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## A New Austrian Passenger Cableway

The cableway shown in the accompanying illustration has recently been completed to transport passengers to the top of the Bauerkohlern in the Tyrolese Alps, in the western corner of Austria-Hungary, from the city of Botzen, in the valley below. It replaces an old aërial cableway, originally built to transport freight onto the Kohlererberg, but which, up to November, 1910, had also been used for passenger service.

The new cableway starts from a bridge over the River Eisack and runs over a double steel cable supported on 12 steel towers of the type shown in the illustration, to the top of the mountain. The difference in elevation between the terminals is about 2755 ft., and the length of the line is almost exactly one mile.

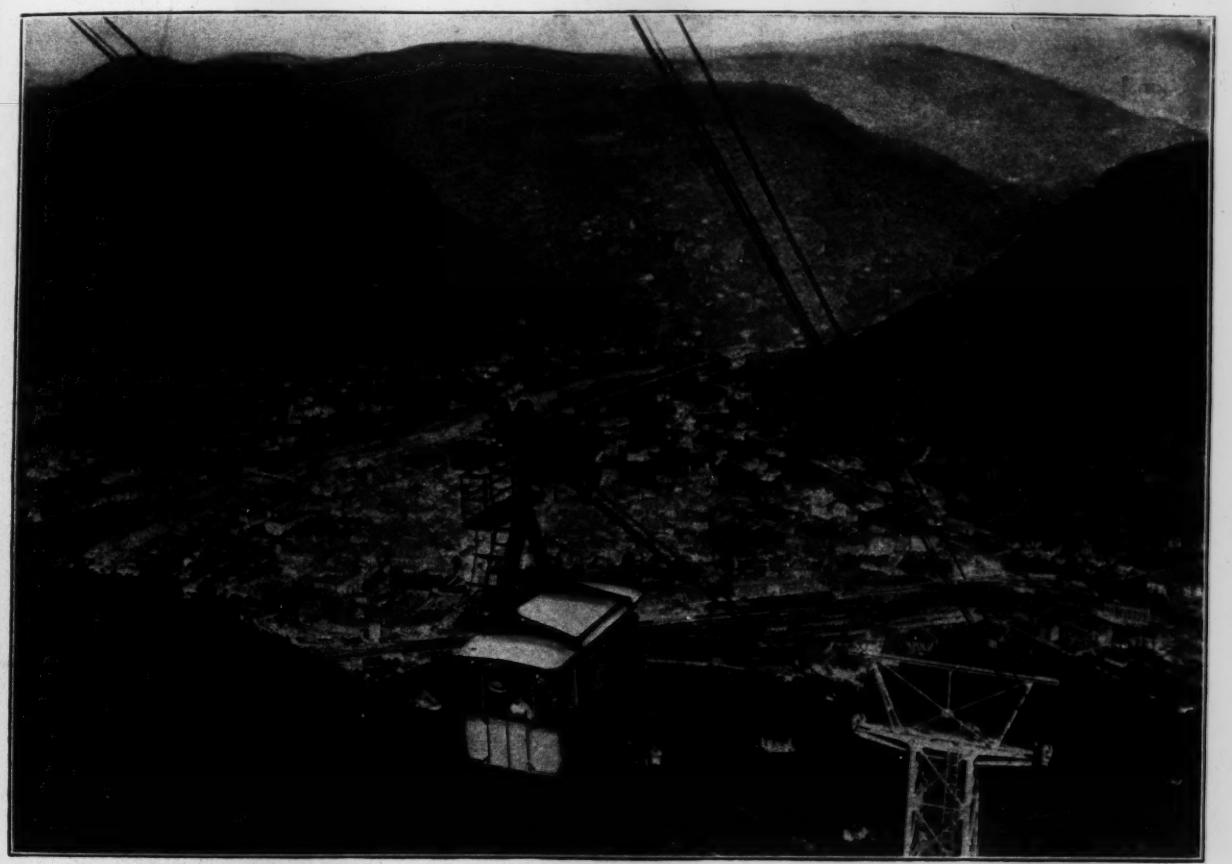
Each of the cars will carry 16 passengers and is equipped with the most approved brake and safety appliances. The double traction cables are wound on drums driven by electric motors at the upper station. Ample provision has been provided to connect the two stations and to furnish means of communication between either station and the cars by signaling and telephoning devices.

The cableway and equipment are very similar to those of the Wetterhorn cableway incline, described in detail in ENGINEERING NEWS of July 22, 1909. The Wetterhorn cableway has a rise of 1370 ft. in a horizontal distance of 1197 ft.

The only passenger aërial cableway in America is on Sunrise Peak, in Colorado, and extends from near Silver Plume, Colo., the terminus of the famous Georgetown loop of the Colorado & Southern Ry., to the summit of the mountain, 12,500 ft. above sea level. The length of this cableway is 7000 ft., and it has a total rise of about 3300 ft. The towers are built of native pine and Oregon fir. A complete description of this cableway may be found in our columns of Oct. 26, 1911.

Besides the Wetterhorn cableway, already referred to, there are several others in Europe, which have been constructed for the purpose of transporting passengers. With the safety appliances now used they offer easy and efficient means of transporting tourists in mountainous regions, and their increasing numbers are evidence of their popularity with the traveling public and of their general freedom from accident.

The Kohlererberg cableway was built by Adolf Bleichert & Co., of Leipzig and London, to whom we are indebted for the data describing it.



NEW PASSENGER CABLEWAY FROM BOTZEN TO THE TOP OF MT. BAUERKOHLERN

# Reminiscences of the Early Days of Fireproof Building Construction in New York City

By M. A. Brooks*

The razing of the fire-ruined building of the Equitable Life Assurance Society at 120 Broadway, New York City, which has now been nearly completed, revealed many interesting reminders of the early use of iron work in connection with building construction in this city. Some of the ideas embodied in the Equitable building have long since been superseded as a result of the development of the steel-cage style of construction, but others have not been improved upon.

As an example of the latter may be cited the method of anchoring the I-beams used in the floors. These were supported at either end by bluestone templates in the brick walls and anchored by straps-

George B. Post

irons to pins set upright in the brickwork. This method is still regarded as the best practice in this class of construction.

When the Equitable building was begun, in the late '60's, only five other buildings in the city contained ironwork. They were Cooper Union, the Herald building, on the site of the old Barnum museum, where the St. Paul buliding now stands, the Times building, the American Exchange Bank and the Ball & Black store on Broadway. Two more were in process of erection—the County Courthouse in City Hall Park and the National Park Bank.

The above named buildings were the first in which iron floor beams were used in this country and were probably the first in the world to use rolled beams. Some cast-iron girders had been used to a limited extent in some English buildings.

The I-beam had just been perfected by Peter Cooper, who invented it. Mr. Cooper had a few years before been commissioned to make fireproof the floors of Nassau Hall, a stone building at Princeton College, which result he accomplished by the use of railway rails. He was then about to build his great gift to the people of New York City, Cooper Union, and he used in it the first I-beams ever rolled.

In that building, as well as in the other buildings mentioned above, these beams were used just as wooden floor joists had heretofore been, being spaced at fixed distances apart without reference to their strength or the load they were to carry. By this practice much iron was, of course, wasted.

The plans for the Equitable building were selected as a result of the first architectural competition in the history of the New York building trade. A number of architects had been invited to participate, and the board was unable to decide between the plans of Guilman & Kendall and those submitted by George B. Post, then a young man. The matter was compromised by placing Mr. Post in charge of the ironwork, elevators and vaults and giving the other details to the older firm.

When the bids for the structural ironwork were opened, the lowest bid was $280,000. Mr. Post thought some money could be saved there, and he devoted himself to the task of figuring out the strength of the various I-beams, there being then no published formulas. He ascertained the load to be carried, and prepared an entirely new plan for the ironwork, which was a nine-days wonder to the builders. In one case Mr. Post specified 6-in. beams for a certain short span, at which the building foreman shook his head. In a day or two, however, he declared himself satisfied they would carry the load. On being asked as to his change of mind, he admitted that he had had 40 tons of granite laid on them over night to test their strength! The cost of the ironwork under Mr. Post's revised plan, including all iron studding and lathing, was $147,000.

The Equitable building at the time of its destruction by fire last winter was really a succession of buildings on the block bounded by Broadway, Cedar, Nassau and Pine streets, the oldest being that on the southwest corner at Broadway and Pine St. When the time came to add to the height of this building, Mr. Post found that instead of the solid brick walls which were supposed to be behind the granite facing, there was instead, due to scamping by the former contractor, only a succession of brick flues, which would carry no more than the load already on them. Mr. Post solved the problem by transferring the load of the additional stories to the granite, and he built the façades, cornices and dormers of copper, fashioned in imitation of stonework.

In one case it was necessary to remove a portion of a bearing wall without disturbing the tenants above. This Mr. Post accomplished by placing an I-beam on either side of the wall and transferring the load to these beams by means of thin steel wedges driven in from either side—a feat not unusual at the present day but an innovation then.

All this work was done, of course, upon shallow foundations, and more or less settlement of the building had to be taken into account. The accompanying photograph shows a construction adopted to guard against injury to the building by unexpected slight settlement on the

A Cast-Iron Column in the Old Equitable Building, Showing Wedge Blocks at Top and Bottom

Cedar St. side near Nassau. The wedges shown were inserted between sections of a column over a bed of quicksand to enable the frame to be leveled up in case of need. Another original idea, which attracted the notice of nearly all the architects of the day, was carried out in the floor of the third story, where it was necessary to move a bearing wall a distance of about 12 ft. Mr. Post lengthened the iron floor beams by clamping larger ones on either side, making the lap about 2 ft. long. These splices were objects of much curiosity as the building was pulled down.

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In remodeling the front part of the building, it was found necessary at one time to renew the lower part of one of the cast-iron columns. The problem of sustaining the load above meanwhile was solved by Mr. Post by clamping to the column a cast-iron friction clutch against which the jacks were placed. So anxious was he about the safety of this device that one night he came downtown after midnight to see if it was still holding. This, Mr. Post says, was the only construction worry that ever kept him awake at night!

During the original construction work, it was reported to Mr. Post one day that the forged brackets under a girder supporting a wall on which rested a number of 15-in. girders, which in turn carried numerous floor beams, were failing by crumpling in the angles. This was serious and there was more or less excitement. Upon inquiring as to the cause it was found that a vault contractor had piled nearly 50 tons of material directly over the sagging portions.

Mr. Post had a forge brought and some saddle irons made. These were heated to a dull red and were clamped hot around the girder supported by the crumpling brackets. When they cooled the frame, vault material and all, was brought into exact alignment again. These saddles remained in service until removed by the workmen who dismantled the building. It was directly over this spot that two big tanks, during the fire crashed down through all the floors above, but stopped at this one.

When the Equitable building was planned, the limit of height in New York City for office buildings was four stories. Tenants could not be induced to climb higher. Only three elevators were in use in the city. One was in the Fifth Avenue Hotel and one in the Astor House, these cars being raised and lowered by the operation of a long screw which passed up through the center of the cage. The third was a car in an apartment house which was lifted by a rope cable by steam power.

In making the Equitable building plans, Henry B. Hyde, then Vice-President of the Equitable, maintained strongly that by means of elevators tenants could be attracted to the upper floors, in which view Mr. Post coincided.

Approval of this revolutionary innovation was not easy to obtain. A prominent real estate firm was asked to appraise the rents in such a building, and when their report was read to the directors Mr. Post, who was present, offered to take the topmost Broadway suite at the appraised rental. "No," declared Mr. Hyde, "you will take the suite at twice that figure," to which Mr. Post agreed. The judgment of both these pioneers was vindicated later when Mr. Post was offered a bonus of $6000 for his lease within six months after the building was opened. The installation of the original elevators was in charge of Mr. Post and they were the first commercial elevators used in America.

The third important section of this pioneering—for it was mostly pioneer work on the Equitable building—entrusted to Mr. Post was the building of the fireproof safety vaults. When these were decided upon as a feature of the building, there were no such vaults in existence. Plans for them were, therefore, evolved entirely from Mr. Post's brain. It stands to his great credit that in these original vaults, after the fire which destroyed the building had been extinguished and they had been opened, every bit of their contents was found to be in perfect condition. This fact has afforded Mr. Post more satisfaction than anything else in his experience.

Shortly after the completion of the first Equitable building, Mr. Post became the Equitable's official architect, and so continued for over 30 years, having charge of the expenditure of many millions of dollars for the company in that time.

Mr. Post became an architect as a result of the great panic of 1857. He had just graduated from New York University as a civil engineer, but there was no work for civil engineers. In that year the eminent American architect, Richard Morris Hunt, returned from Europe where he had studied under Lefuel and had been connected with many famous architectural works abroad. Mr. Hunt gave instruction to a few pupils in architecture at that time, and Mr. Post was invited to be one of the class. He consented, and afterward devoted himself entirely to architecture.

Mr. Post is now 74 years old, but his eye is keen, his hand steady and his mind clear. He motors in from Bernardsville, N. J., nearly every day to oversee the work in his office on Fifth Ave.

## Co-operation of Engineers for Fire Prevention*

If we take the annual fire loss and add to this the excess cost of fire protection due to bad construction, and excess premiums over insurance paid, we have the grand total of $456,485,000, an annual tax which must be met by the property and nonproperty holders—the people of this country. This sum represents one of our questionable luxuries. It is a leak pure and simple. Considered comparatively, it is one-half enough to defray the annual expense of our Federal Government. It is more than the total value of all gold, silver, copper and oil mined in this country during the year 1907. It would have built four fleets of Russian ships like the two destroyed by the Japanese, or it would about dig and equip the Panama canal—all this just one source of waste of property each year in this country.

In European countries they have reduced the per capita loss to considerably below 33c. in many parts, as in densely populated cities, where the risk normally would be very great. Rigid, I might say severe, laws, vigorously enforced, have brought this result. Instance these laws in force in France.

> The tenant is responsible for a fire on his premises unless he can prove the fire was caused by something beyond his control, by some fault in building, or that the fire was communicated by a neighboring building.
>
> Every person is responsible and liable for any act of his by which any other person has or may have sustained any loss, damage or injury.
>
> Every person is responsible for any loss, damage or injury caused by his own act, carelessness or neglect.

These laws of France and the still more rigid laws of Germany show the spirit and purpose to have no loss if it is possible to prevent, and they certainly approach the limit for efficiency.

It may seem a far cry to urge upon the engineer the necessity of weighing the probability of loss from interruption of production traceable in many instances to flagrant disregard of well established practice for fire protection. In many instances such inadvertence is nothing short of a crime, looked at sociologically, to say nothing of the direct waste of money values. What engineer does not figure factor of safety against breakdown of parts? Does every engineer figure factor of safety against loss by shutdown from fire? Le our engineers get the government idea. Build in a manner such as will reasonably insure indestructibility.

It is said the Federal Government owns about $300,000,000 in buildings and is annually adding to this $20,000,000, while it carries no insurance at all. The annual premium would amount to $600,000 did it carry insurance. This possible premium means an annual saving of 3% on the annual expenditure for new buildings, or a cumulative 3% fund which each year after the 23d year will refund the annual $20,000,000 outlay for new buildings. There may or may not be anything new in this hint at the creation of a depreciation fund from what would otherwise have represented to the government fire waste, but that does not qualify the cold fact in the case.

From 20 to 25 years is commonly taken as the life of a building, plant or other product of engineering skill, and such as come under the head of insurable properties may be so improved upon in design, or materials, or location that the refunding of depreciation account may be affected in the manner shown and still we shall be behind other nations in the matter of curtailment of fire waste.

*Extract from the paper of H. L. Vorse, before the Oregon Society of Engineers. "Journal" of the Association of Engineering Societies for October, 1912.

# Structural-Steel Towers and Poles*

By R. Fleming†

## Wood, Concrete and Tubular Poles

According to the U. S. Census there were 3,870,000 wooden poles purchased during 1910. Of these 62% were cedar, 18% chestnut, 7% oak, the remaining 13% being pine, cypress and other woods. Classified according to length 17% were under 20 ft., 56% were 20 to 30 ft. (this being the length most commonly used by telegraph and telephone companies), 21% were from 30 to 40 ft., 5% were from 40 to 50 ft. and 1% over 50 ft. The bulletin from which the above statistics are quoted gives the number of poles purchased in 1909 as 3,738,000; in 1908, 3,249,000; in 1907, 3,283,000. Of the poles purchased in 1910 about 21% received some kind of preservative treatment before being set in place.

For 1909 the average first cost of wooden poles purchased was but $1.89. So from the financial standpoint nothing has been found to take the place of wood for the ordinary telegraph or telephone line pole. The cost of renewals and maintenance is not great enough to warrant the additional first cost of either concrete, iron, or steel poles, and wood will continue to be largely used for some years to come.

Wood is increasing and fabricated steel is lessening in price. Fewer poles or towers are required if made of steel than of wood as they can be placed farther apart; this means fewer foundations, crossarms and insulators. In many cases, as for distribution systems in the yards of shops, wooden poles are not strong enough to carry the loads that will come upon them. Municipal authority has sometimes required the wooden pole on the city street be replaced by the steel pole. The fire risk is eliminated with the steel support, and this is important. A substitute for wood is therefore in many cases not only desirable but necessary.

Reinforced concrete is being used to some extent for distribution lines of electric-light and power companies, and also for overhead construction of street railways. The general tendency seems to be in the direction of a more extended application.

Tubular poles, made of successive lengths of iron pipe, take up little room, present a round resisting surface to external loads, show excellent results when tested, and can easily be repainted when necessary. Their limitations as to size restrict their use to light loads.

*From a paper presented at the annual convention of the Association of Iron and Steel Electrical Engineers, Milwaukee, Wis., Sept. 30 to Oct. 5, 1912.

†American Bridge Co., 30 Church St., New York City.

## Structural Steel Towers

This paper will be restricted to structural-steel supports—either poles or towers. The treatment of reinforced-concrete poles, tubular poles, or the different patented poles on the market will be left to others. The literature on steel towers is extensive—that on steel poles is limited.

We have yet no form of either pole or tower that can be called "standard." Present-day practice for poles is crystallizing about the latticed four-angle type. Towers are being built mostly of the square wind-mill type. An exception is the 140,000-volt line put in operation this year in Michigan, where the towers, of which there are 10 to the mile, are of the braced-tripod type, composed entirely of galvanized-steel angles. This line, at present 125 miles long, is being extended a hundred miles farther and carries the highest voltage yet undertaken, the previous maximum being 110,000 volts.*

While the electrical features of a transmission line have received careful attention by the electrical engineer, the structural features have often been taken care of in a crude way, or left largely to chance. The electrical engineer fails sometimes to realize there are other problems to be solved besides those of a purely electrical nature. He should work with his brother, the structural engineer, as the chief item of cost in a transmission line is the structural-steel supports.

Loads—In designing either a pole or tower the first question for determination is the loads to be carried. These loads are of three kinds: (1) Vertical or dead loads: (2) loads at right angles to the direction of line, due to lateral wind pressure; (3) unbalanced loading in the direction of the line, due to breaking of wires. The forces of these three loadings are at right angles each to the other.

(1) The vertical or dead loads are: (*a*) the weight of the structure itself; (*b*) the weight of the wires supported by the structure; (*c*) the weight of the snow or ice coating, if any, on the wires. In sleet regions, ice is generally assumed to accumulate ½ in. thick around the wire. These vertical loads are easily determined, but are seldom a governing feature in the design of the structure, except for the crossarms. The crossarms should be designed for a minimum load of 1000 lb. at each end. They carry not only the insulators and wires but at times a man or two to adjust them.

(2) The lateral wind pressure on transmission lines has been much discussed. Well known engineers have arrived at widely different conclusions. The author of the article on "Electrical Power Transmission in the Encyclopedia Britannica" writes:

*See Engineering News, May 16, 1912.—Ed.

> The actual possibility of wind pressure is very generally over-estimated, and has resulted in much needlessly costly construction.

Another writer (Joseph Mayer, Engineering News, Jan. 4, 1906), says:

> Such lines should, therefore, be built strong enough to resist not only the commonly occurring, but also the exceptionally violent local storms.

From a mass of data, the writer recommends the use of the following wind loads: (*a*) On the structure itself, 30 lb. per sq.ft. of exposed surface; (*b*) on bare wires, 15 lb. per sq.ft. of projected area (length multiplied by diameter); (*c*) on wires covered with ½-in. coat of ice, 10 lb. per sq.ft. of projected area. In a sleet region (*c*) should be followed as it is the more severe.

It is noted at once that the requirements given for (1) and (2) do not in themselves determine the loads on the towers or poles unless their distance apart is known. In laying out a transmission line the first thing to find is the most economical span. This is both an electrical and a structural problem. The voltage, size and kind of wires, are to be decided. With these given, the spacing of towers can be determined. The foundations also enter in the calculations. Empirical formulas have been given for the most economical span, but so many variables enter into the question, that they can only be regarded as approximate. Each line is a problem by itself and must be solved independent of all other lines.

(3) The assumptions regarding unbalanced loading in the direction of the line will often determine the design of the tower. Practice as well as theory varies widely in this respect. The following is recommended: A tower having three line conductors or three conductors and one ground wire should be designed to withstand the unbalanced load due to any single wire breaking; a tower having six line conductors or six conductors and a ground wire should be designed to withstand the unbalanced load due to any two wires breaking. The breaking of a wire throws upon the wire in the adjacent span and thence to the tower a load equal to that which caused the wire to break. For the smaller sizes of wire, No. 4 and under, this load should be taken as the ultimate strength of the wire itself. For No. 3, 90%; No. 2, 80%; No. 1, 70%; No. 0, 60%; and for No. 00 and larger wires it is recommended that 50% of the ultimate strength of the wire be used. The reason for the larger wires being given an advantage is that a break is not liable to occur in them until there has been a reduction of cross-section from burning due to a short-circuit from any cause. The smaller sizes will not permit any reduction of section without breaking.

For line conductors hard-drawn copper wire is generally used. The American Steel & Wire Co. find, from tests, the

elastic limit of their copper wire to be 34,500 lb. per sq.in. and more and the tensile limit from 50,000 to 65,000 lb. per sq.in. For No. 00 copper wire, a size often used, the longitudinal pull due to one wire breaking will be 2500 lb.; for No. 0000 copper wire 4000 lb. will answer. Care must be taken to provide for torsional stresses caused by unbalanced loading.

In designing the standard towers of the line, the material is to be proportioned for maximum stresses due to any combination of loads (1), (2) and (3).

UNIT STRESSES—Equally important with assumed loadings are assumed unit stresses. It might be well to divide proposed towers into three classes—(A), (B) and (C), and assume unit stresses in accordance with the classification of the tower. Two prominent features to be considered regarding any line are the importance of uninterrupted service and the probability of loss of life, due to accident of wires or towers giving way. If the purchaser of power insists upon service at all times under heavy penalty, the tower would come under (A). If interruptions under certain limitations are allowed, (B) may answer. From the standpoint of loss of life due to accident, a line over a thinly settled mountain country would come in (B), while the thickly settled zone about a town or city would require (A). Using open-hearth steel with an ultimate tensile strength of 55,000 to 65,000 lb. per sq.in. and an elastic limit of 55% of the ultimate strength, the working unit stress of steel in tension may be taken at 22,500 lb. per sq.in. for (A) and 27,000 lb. per sq.in. for (B). For steel in compression the recommended formula is:

$$\frac{22{,}500 \text{ or } 27{,}000}{1 + \frac{l^2}{18{,}000\, r^2}}$$

To (C) is consigned poles and towers where the primary feature to be considered is the cost. The question then too often becomes, not what the structure should be, but what are the least requirements that can be exacted and the line probably do its work. A common method of reducing material is to consider loadings (2) and (3) not acting at the same time, and increasing the unit stress to 30,000 lb. per sq.in. Some engineers think a high wind will not occur when the wires are covered with sleet.

Even admitting this to be true, arcing sometimes happens between wires when there is a high wind on the bare wires. Owing to lightning discharges, accompanied with wind, it may happen over insulators. This is certainly a combination of (2) modified, and (3) which should not be neglected. For wires covered with ½ in. coat of ice, 8 lb. per sq.ft. of projected area for wind load is considered allowable by some good authorities. To this there is not the objection as to the use of 30,000 lb. per sq.in. for unit stresses. The latter comes too near the elastic limit of the steel likely to be used.

It may be said here that comparatively few existing towers are of classes (A) or (B). The engineer often finds it a commercial impossibility to have the towers built as he would like to design them. The situation is similar to that of the highway bridges 30 or 40 years ago. The bridges of that day would not be tolerated now. The towers of today will not be tolerated a generation or two hence.

TESTS—Specifications often require that towers withstand certain artificial tests. This means the minimum amount of material that will meet these tests will be used regardless of other considerations. The conclusions from artificial tests are often misleading. The material is new and in good order, and there is the friction of pieces bolted or riveted close together. The workmanship for the test pieces has at least not been slighted. The structure is assembled at the shop under more favorable conditions than will exist in the field. The loads are applied gradually and in one direction, quite different from those that will come after erection. The test generally takes but an hour or two, while the structure is built to last for years, during which it is subject to a continued test.

What is wanted in steel work is *durability*. This cannot be assured by a structure simply meeting an artificial test. It may be noted that almost every bridge that has failed or had to be replaced was "tested" before acceptance. This does not mean that a mechanical test has no value. The contention is that an artificial test alone does not give the true value.

For poles which are composed of few pieces and are of simple construction, a greater value may be placed upon the test than for towers which are made up of a multitude of pieces and are complicated in their structure, but for both poles and towers conditions should be imposed regarding thickness of material, relation of unsupported length of column to radius of gyration, and details—the last being considered especially important.

SPECIAL CASES—A careful study should be made of special cases of loading. Generally when a pole or tower fails it is under conditions for which it was not designed. Horizontal and vertical angles in the line should be considered. Some English specifications allow the standard tower to be used without further calculation when a horizontal angle in the line does not exceed 8°. American specifications often allow this angle to be 10°, though there is no uniformity of practice in this respect. Frequently standard towers are used and the approach spans are decreased. In one large system, where the average cable span length on tangents for level country is 550 ft., the approach spans to angles in the center line vary from 400 ft. on angles up to 8° to 100 ft. on angles of 45°, the maximum angle turned on one tower. Sometimes a standard tower is used and guyed. This is generally objectionable. The most satisfactory practice is to use a tower calculated to withstand the increased loads due to the deviation in the direction of the line. Poles or towers adjoining railroads should be designed to meet special requirements. The specifications issued by some railroad companies for lines crossing their right-of-way are quite severe. The National Electric Light Association's "Specifications for Overhead Crossing of Electric Light and Power Lines" are less stringent. Poles used about manufacturing plants will be mentioned later.

"FLEXIBLE" TOWERS—What are known as "flexible" towers originated in Italy a few years ago, and are being used to some extent in this country. Semenza, an Italian engineer, conceived the idea of caring for the longitudinal forces in a line through a flexible system rather than by a single rigid tower. By this method an occasional tower, about one in ten, is "dead-ended" or made perfectly rigid to take longitudinal stresses, the intervening towers being made to withstand only the dead weight and transverse wind loads. If a wire breaks there is a drop in the catenary and the shock is absorbed into the series of poles by each yielding at the top. The "dead-end" tower being designed for all the wires breaking, prevents the longitudinal pull extending farther along the line. The intermediate or standard towers are generally made A-shape of two channels latticed together with angles. The advocates of this method are enthusiastic over the saving they claim in steel material and foundations.

A point generally overlooked in making a comparison between the flexible and the rigid towers is that if flexible towers are used either heavier wire or higher towers are required. With the rigid type, if a wire breaks, the tower at each end will take up the unbalanced loading. In the flexible type, say with three line conductors and a ground wire, if a wire breaks the tops of the towers on either side of the break will be pulled over by the four cables in the next span until the total tension in them would be just balanced by that in the remaining conductors of the damaged span. That is, the three cables remaining would do the work of the four in the adjoining spans, showing the need of heavier wire. Of course, this unbalanced loading can be taken up by a greater sag and less tension in the cables, but this necessitates higher towers to maintain the required clearance underneath the wire. It is an open question just how far flexible towers are to be commended. Does the reduced cost overbalance the lessened reliability?

For low voltages with towers or poles comparatively short distances apart, they may sometimes be used to advantage. Where high voltages are used with but eight or ten towers to the mile, rigid towers should be used. The City of Winnipeg in its municipal line from Pointe du Bois on the Winnipeg River to the city, a distance of 72 miles, compromises on the choice of towers. Rigid towers are spaced 1200 ft. apart with a flexible tower midway between. Towers are 43 ft. to the crossarm and carry a double circuit or six wires.

FOUNDATIONS—It matters little how near perfect the superstructure may be, if it rests on insufficient foundation. It

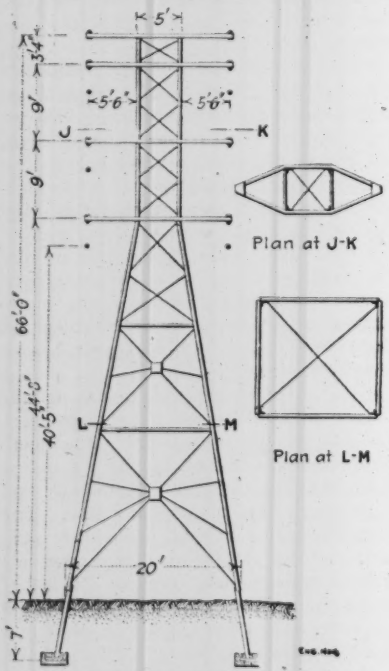


FIG. 1. STANDARD TRANSMISSION-LINE TOWER, CONNECTICUT RIVER POWER CO.

will then fail in the hour of stress. The theoretical considerations governing the design of foundations are well known, but it is folly to design these foundations in an office, unless it is known the assumptions made fit the actual conditions of the soil at the site. The attempt to do this will probably result in a footing with an undue margin of stability, causing unnecessary expense, or a footing of insufficient strength, liable to cause trouble ever after. Especially to be condemned is a prevalent practice of placing the steel anchorage without any thought of surrounding conditions. Some towers recently built showed excellent results when tested at the shop in the usual way by firmly fastening the foot of each leg to a heavy steel frame. In the field they were pulled over without any difficulty. The soil yielded and the steel anchorages pulled out. Such designing, or lack of designing, is foolish.

The usual method of anchoring is to run an angle stub 5 to 8 ft. in the ground. This stub extends a foot or so above the ground level, and at the top are open holes for bolts to take the corner legs of the tower. At the bottom of the stub is a cross piece 3 or 4 ft. long of either channels or angles. This anchorage is placed in a hole dug in the ground and the hole refilled. For light lines with short spans and good soil, this may be sufficient for a time. For the usual long-span transmission line, the overturning moment due to the side wind pressure becomes much larger. A platform at the bottom of the angle stub can easily be designed to withstand the uplift, if the soil conditions are known.

Without any protection save a coat of galvanizing, corrosion is bound to set in at or near the ground level. The writer, a year ago, saw some towers in a cultivated field against the corner angles of which the soil had been turned in plowing. The galvanizing had nearly disappeared, though the towers had been erected but two years. There is trouble at no distant future for those towers. The anchorage should extend not less than a foot above the ground line and should be entirely encased in concrete; though a sleeve of concrete extending from the top to two or three feet below the ground line is sometimes used. Here at once a practical objection is raised. To get water and material at the site of the various towers of a transmission line, make concrete and properly set it, is difficult and expensive. Unless a strict supervision is exercised the work is sure to be slighted.

Thicker steel sections used for the anchorage will delay, but not prevent, failure from corrosion. It has been suggested that the anchor stubs be designed in two lengths, the upper length to be removable and thus replaced without tearing down the tower. A large line installed last year used a preservative paint instead of galvanizing their anchorages.

LIFE—The life of a wooden pole is given, if of cedar, as from 15 to 20 years, and longer if preservatives are used. The life of a steel pole or tower cannot yet be definitely stated. It is only as far back as 1903 that the first high-tension transmission line was built in which steel towers were used exclusively. This was a line 101 miles long in Mexico, with towers about 450 ft. apart. The present practice of a multiplicity of light sections will not be conducive to long life. Sections ⅛ in. thick are very common—more of this thickness than of any other are used in the average tower. Towers made of such material, galvanized at the shop, bolted together in the field, and then left alone cannot last for a long term of years.

The use of unusually thin metal for compression values calculated in accordance with accepted formulas is to be criticized. In a number of tower tests, under the writer's observation, the failure was always in the 4x4x¼-in. corner angle leg. They were not good for the calculated value. This confirms Talbot & Moore in "An Investigation of Built-up Columns Under Load"* in which they write:

> It would seem quite probable that, for columns of the same length and containing the same amount of metal, one which is of stocky form and in which the metal is distributed so as to resist local flexural and torsional action will be much stronger and more satisfactory than a column of more flimsy form, which has its metal spread in thinner sections, even though the slenderness ratio l/r of the former may be considerably more than that of the latter.

Important changes will take place in the direction of thicker material after some of the present lines fail, and the present policy of purchasing only what will answer for the immediate present is abandoned. There is no reason why a

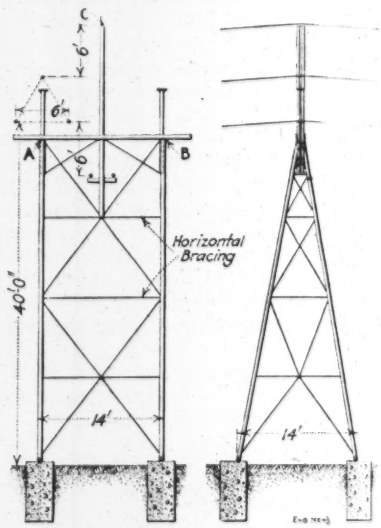


FIG. 2. STANDARD STRUCTURAL-STEEL TOWER, GEORGIA POWER CO.

tower properly designed, inspected at regular intervals, painted when necessary, should not last 50 years, perhaps longer.

### EXAMPLES OF TOWERS

CONNECTICUT RIVER POWER CO.—The 917 towers for the line of the Connecticut River Power Co. were designed and built by the American Bridge Co. Of these towers, 862 are the standard, shown in Fig. 1. The specifications, drawn up by J. G. White & Co., call for the strength of these towers to be as follows:

> The towers shall be designed for, and shall be guaranteed to stand, the following test loads without stressing any member beyond its elastic limit:
> Insulator Pins and grounded wire cap: (1) At top of insulators for line conductors, 1600 lb. in any direction perpendicular to pin axis. (2) At top of iron cap support for grounded wire, 1400 lb. in any direction perpendicular to axis of support.

*Bulletin No. 44. University of Illinois Engineering Experiment Station.

Supports for pins and cap:
(3) 1400 lb. load in any direction on grounded wire cap and 1600-lb. loads in any direction on line conductor insulators to be applied singly or in any combination to produce maximum stress in the supports.
Main tower structure:
(4) A load of 4800 lb. in any direction at point A (Fig. 1), and no load at B and C.
(5) A load of 4800 lb. in any direction at points A and B, together with a load of 1400 lb. in any direction at point C.

In proportioning material the unit stresses were taken at 24,000 lb. per sq.in. net for tension and for compression,

The test load shall be: (1) A longitudinal pull of 4300 lb. at right angles to the end of any one cross-arm. (2) A vertical load of 1500 lb. at the ends of any or all cross-arms. (3) A load of 1500 lb. pulling in any direction at the top of tower. (4) A load of 10,000 lb. pulling at right angles to the line or parallel to the cross-arms, that is, 2500 lb. at each cross-arm. At the same time a pull parallel to the line or at right angles to the cross-arms of 8000 lb., that is, 4000 lb. in the same or opposite directions at each end of any single cross-arm or at one end of any two cross-arms.

Crossarms are proportioned for combined loading (see section on "Loads" under "Towers" above) of Case 1, which they are designed are: (1) A longitudinal pull of 3000 lb. at right angles to the end of any one crossarm. (2) A vertical load of 1200 lb. at the ends of any or all crossarms. (3) A load of 1200 lb. pulling in any direction at the top of the tower. (4) A load of 8000 lb. pulling at right angles to the line or parallel to the crossarms, that is, 2000 lb. at each crossarm. At the same time a pull parallel to the line or at right angles to the crossarms of 5000 lb., that is, 2500 lb. in the same or opposite

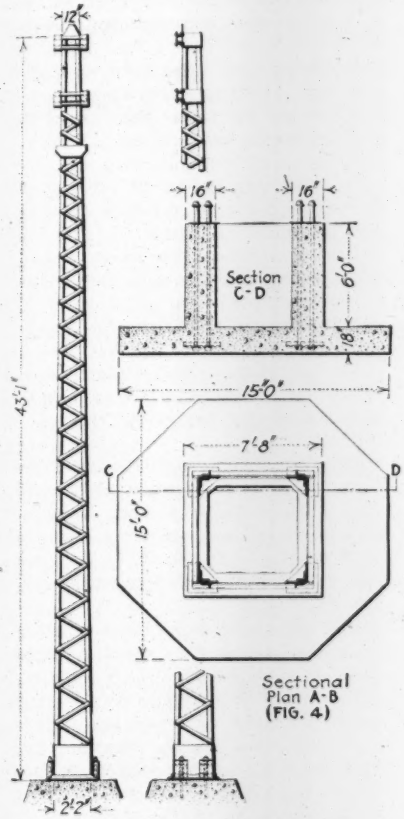


FIG. 3. STANDARD 40-FT. TWO-ARM STEEL POLE, INDIANA STEEL CO.

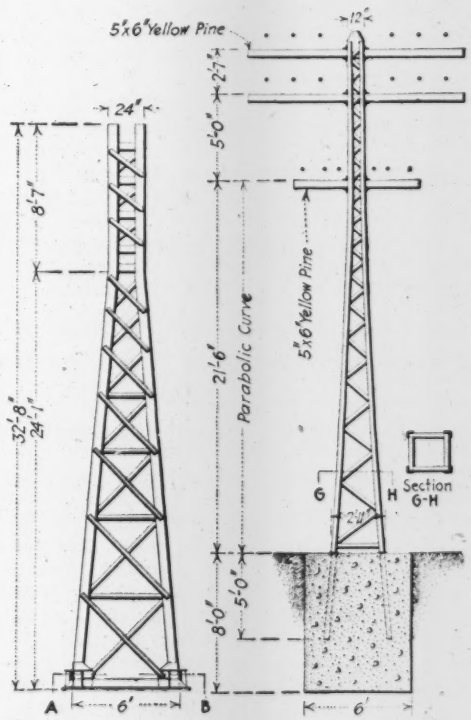


FIG. 4. TYPICAL ELECTRIC-LINE POLE FOR RAILWAY YARDS, WESTINGHOUSE, CHURCH, KERR & CO.

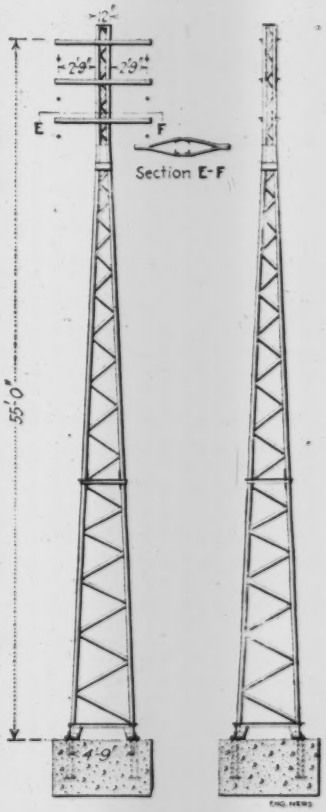


FIG. 5. STANDARD TRANSMISSION-LINE POLE, N. Y. C. & H. R. R.R.

FIG. 6. STANDARD STEEL POLE OF THE TRI-CITY RAILWAY & LIGHT CO., DAVENPORT, IOWA; J. G. WHITE & CO.

$$\frac{24{,}000}{1+\frac{l^2}{13{,}500\,r^2}}$$

GEORGIA POWER CO.—Some towers designed and built by the American Bridge Co. for the Georgia Power Co. are shown in Fig. 2. Suspension insulators are used. There are 735 towers of the dimensions shown in cut carrying six line conductors of No. 0000 copper wire, and two $\frac{7}{16}$-in. galvanized-steel-strand ground wires. The data drawn up for the Georgia Power Co. by the Northern Contracting Co., C. O. Lenz, Chief Engineer, from which the towers are designed follow:

Case 2, and 1250 lb. horizontal thrust at end of arm. The tower is proportioned for maximum combination of Cases (2) and (3), or (2) and (4). Unit stresses used are 25,000 lb. per sq.in. net for tension and for compression

$$\frac{25{,}000}{1+\frac{l^2}{18{,}000\,r^2}}$$

There are also 816 standard towers carrying six line conductors of No. 00 copper wire and two $\frac{3}{8}$-in. galvanized-steel-strand ground wires, the towers being 16 ft. square at the base and 70 ft. to the upper crossarm. The loads for directions at each end of any single cross-arm or at one end of any two cross-arms.

The combination of loadings and unit stresses is the same as for the towers with No. 0000 wires.

In addition to the above standard towers there are 200 towers designed to meet special conditions.

### STRUCTURAL-STEEL POLES

It has been requested that structural-steel poles be given a prominent place in this paper. Much of what has been written is intended to

be applicable to either poles or towers, though for transmission and distribution systems about the yards of manufacturing plants some of the conditions are quite different from lines through great stretches of open country. The size of base is restricted to as small an area as possible. This necessitates a pole instead of a tower.

The loads to be carried and the desired permanency demand a steel instead of a wooden pole. An interruption of service, even for a short time, means inconvenience and loss. Accidents to life and property, if they occur, are liable to be disastrous and must be guarded against. The seriousness of failure on such lines will justify heavy construction. For this reason it is recommended that each pole be designed to withstand in addition to the dead and wind loads the unbalanced load due to a majority of the wires coming upon it being broken. All conditions such as the probability of wires being added in the future, the deviation of the line from a tangent, or special loadings, should be considered. A unit stress of not more than 16,000 lb. per sq.in. net for tension and the same reduced by previous formula for compression should be used.

The anchorage and foundations should be carefully designed in accordance with local conditions. These local conditions should be thoroughly understood. A clause from the specifications of New York Central & Hudson River R.R. for lines crossing railroads is applicable here:

> The foundations shall be of concrete and shall be designed so as to be able to resist double the greatest tendency to overturn due to any combination of the loads specified. No steel shall be carried below the surface of the ground unless encased in concrete. The tops of foundations or tops of the concrete casing shall not be less than 12 in. above the ground and always above flood water.

INDIANA STEEL CO.—The latest word in the various departments of steel manufacturing may be found at Gary, Ind., in the plant of the Indiana Steel Co. Attention is called to a paper in the *Transactions* of the American Institute of Electrical Engineers for 1909 entitled, "The Industrial Application of the Electric Motor, as Illustrated in the Gary Plant of the Indiana Steel Company," by B. R. Shover. It is valuable on account of the detail with which the writer has gone into so many phases of his subject.

The standard 40-ft. two-arm pole is shown in Fig. 3. The poles and towers throughout are designed to carry the dead load of the construction, including a coating of ice on the wires equal in thickness to the radius of the wire, together with an overturning load of 20 lb. per sq.ft. on the towers, and 10 lb. per sq.ft. on the projected area of the wires; also a torsional stress in any pole produced by an unbalanced load resulting from the cutting of 25% of the wires in the adjacent span. The unit stresses used are those of the American Railway Engineering and Maintenance of Way Association. No material less than $\frac{1}{16}$ in. thick is used.

WESTINGHOUSE, CHURCH, KERR & CO.—R. A. Marshall, structural engineer, has designed and built a number of poles for the yards of railroad shops. Fig. 4 shows a typical pole and its foundation.

Each pole is carefully worked out by itself. The dead loads are the structural steel and the wires with a covering of ice ¼ in. thick. The wind load is figured at 13½ lb. per sq.ft. on projected diameter of wire with ¼-in. ice coating. The tension in wire is figured on a basis of 100 ft. span with 3% sag at center. A number of these poles take pulls at right angles to the main line which adds materially to the stresses. This is not an uncommon feature in the yards of railroad shops and manufacturing plants.

The steel is designed for two-thirds of the computed loadings with a unit stress of 16,000 lb. per sq.in. net in tension and 16,000 lb. reduced by the formula for compression. No material less than ¼ in. thick is used. Observe that the foundation is of ample proportions.

PENNSYLVANIA R.R.—Among the interesting features of the New York tunnel extension of the Pennsylvania R.R. are the poles through the Meadows section in New Jersey.* There are two lines, one for telegraph and telephone purposes, and one for power transmission; they were designed by R. D. Coombs. The poles of the telegraph lines are of concrete, 25 to 50 ft. high and spaced 70 to 135 ft. apart. The poles of the high-tension transmission line are of latticed steel, parabolic outline, square in cross-section, with one angle at each corner and single-angle bracing. They are designed not only for present requirements but a liberal provision is made for future needs. The Hackensack River is crossed midway in the Meadows section. The adjoining poles, at the time they were built, were the highest in this country.

These poles (or tower-poles) are 765 ft. apart. Each one is 15 ft. square at the base and 3 ft. square at the top. The tops of foundations are 6 ft. above high water, and from the top of the foundation to the ground line is 188 ft. 4 in. Special features are: Large number of heavy wires, of voltage requiring some separation, carried at a minimum clear height above high water of 133 ft. No strain insulators were available of sufficient electrical or mechanical strength, therefore nests of pin insulators carrying saddles were used to support the wires on the poles. The poles present a graceful appearance. The base is small in area—a greater spread would further obstruct the river and increase cost of foundation. On account of the importance of the line in operating the terminal division of a great trunk-line railroad, conservative data were used for calculations. These data are as follows:

Wires—

River Span: One 250,000-circ. mils, hard-drawn stranded copper ground wire; twenty-four 250,000-circ. mils, hard-drawn stranded copper line wires; four 250,000-circ. mils, hard-drawn stranded copper signal wires; two 2,000,000-circ. mils, hard-drawn stranded copper feeder wires.

Adjoining span same as river span.

Second adjoining span, same as river span except for signal wires—four No. 00 hard-drawn solid copper.

Loading—

One-half-inch ice on all wires with 8 lb. per sq.ft. wind pressure on diameter multiplied by length.

Thirteen pounds per square foot of wind on 1½ times the pole area.

Normal sag 31.8 ft.

Transvere pull 24,900 lb.

Longitudinal pull 22,135 lb.

Unit stresses: Steel in net tension 15,500 lb. per sq.in.; steel in compression 17,600 lb. per sq.in. reduced by formula.

NEW YORK CENTRAL—The poles near New York City for the electric-transmission lines of the New York Central & Hudson River R.R. are often quoted as good practice. Fig. 5 shows the standard pole carrying 12 high-tension conductors.

It is made of four corner 3½x3½x⅜-in. angles laced with 2½x2x¼-in. angles. Poles on a tangent are 150 ft. apart with a wire sag of 30 in., those on a 6° curve are 107 ft. apart with wire sag of 15 in. The dead loads are the structure itself with the wires covered with ½-in. coating of ice. Wind pressure is taken at 30 lb. per sq.ft. on the surface of the pole and on all wires covered with ½-in. coating of ice. The unit stresses used are 30,000 lb. per sq.in. net for tension and for compression $\frac{30{,}000}{1+\frac{l^2}{125\,r^2}}$. While these unit stresses seem high, the loadings are large. The foundation is a solid block of concrete. The crossarms are of wood, probably to secure greater insulation.

LONG ISLAND R.R.—A similar substantial construction is used by the Long Island R.R. for their steel poles on Long Island. The parabolic outline is abandoned. For the high-tension wires the wind is figured on the bare wire; for the low-tension wires it is figured on the wire covered with sleet ½ in. thick. Wind pressure is figured according to results of German high-speed railway tests, where pressure per square foot = 0.0027 $V^2$. With a velocity ($V$) of 100 miles

*See Engineering News, Oct. 12, 1907, p. 434, for a more detailed description.—Ed.

per hour, wind pressure = 27 lb. per sq.ft. on flat surfaces and 13½ lb. per sq.ft. on projected areas of conductors. Side pull on pole is figured for a center deflection of 6 ft. with poles on 150-ft. centers.

N. Y., N. H. & H. R.R.—The 40-ft. yard poles of the New York, New Haven & Hartford R.R., used in the electrification of the Harlem River Branch, are rectangular in cross-section of four 5x3½ x⅜-in. angles, double latticed on all four sides with 2¼x⅜ and 2¼x½-in. flat bars. The poles, back to back of angles, are 2x3 ft. at base and 2 ft. by 2 ft. 2 in. at top. The base of each pole is made specially strong. From this base, four anchor rods of 1¾ to 2⅛ in. diameter and upset at ends run down 8 to 10 ft. in a concrete foundation.

J. G. WHITE & Co.—Some poles designed by S. R. Jones, structural engineer of J. G. White & Co., are simple in construction. They are for a transmission system in the Middle West and are shown in Fig. 6.

The data upon which design is based is:

Power wires: One circuit No. 1 stranded medium hard-drawn copper; one circuit No. 4 stranded medium hard-drawn copper.

Ground wire: No. 8 copper-clad steel.

Maximum allowable tension in wires: Fifty per cent. of breaking strength with ½-in. coating of ice and wind load of 8 lb. per sq.ft. on horizontal projection of increased diameter of wire.

Assumed loads on pole: Vertical loads: Crossarm = 600 lb. at end of crossarm; pole = weight of pole + weight of wires covered with ½-in. thickness of ice.

Horizontal loads: Total pull of 2500 lb. applied at middle crossarm in direction of line, or at right angles to line plus wind load on pole at 20 lb. per sq.ft. on exposed surface (both sides of pole included in surface exposed to wind pressure).

Unit stresses in steel: 24,000 lb. per sq.in. net for tension; 24,000 lb. per sq.in. reduced by formula for compression.

The preceding poles may be taken as illustrating the best practice of today. It will be seen that they have much in common. In each case the pole is made of four angles latticed.

VARIOUS POLES—A pole made of two channels laced has been used, but such a pole is limited to light loads and low heights. The same can be said of a pole made of one plate and four angles. Foster ("Electrical Engineer's Pocket-Book") gives the deflection of some poles 6 ft. in ground and 24 ft. above ground, made of 6-in. to 12-in. by ⅜-in. plate and four 2½x2x¼-in. angles, for loads of 500 to 2500 lb. applied 3 ft. from the top, to be from 1 to 5 in. These poles were used for electric railway service. The plate-and-angle pole has the advantage of being a good shape for inspection and painting.

Patented poles, made of rolled-steel sections fastened together at intervals are on the market, and are meeting with considerable sale. They show good results for vertical loads, but the sections being battened and not laced together are adapted to carry only light lateral loads to the base. It is the custom to guy these poles from the top if the lateral forces are large. This restricts their use.

### CONCLUSION

The use of steel poles and towers is on the increase. This paper is not intended to be a complete discussion for the field is too varied and too large to be thoroughly reviewed in a single paper. It is hoped, however, what has been written may not be without interest, and lead to further discussion on the subject.

## The Texas-California Arc of Primary Triangulation

The measurement of the Texas-California arc of primary triangulation, 1207 miles long, has been completed and the results have been published in Special Publication No. 11, of the United States Coast & Geodetic Survey, by William Bowie, Inspector of Geodetic Work and Chief of the Computing Division. The fieldwork was begun in September, 1907, and completed in February, 1911. There were 115 stations occupied for horizontal positions, 92 in the main scheme and 23 in. subsidiary schemes. The area in the main scheme is 49,220 sq.mi.

The Texas-California arc has been completed with greater rapidity and at a lower cost than any previous arc of primary triangulation in this country; and probably this survey has not been excelled in rate of progress or low unit cost by similar work in any other country. The reconnoissance was done in a single season by one party. All horizontal angle measurements were made by the direction method, using 12-in. theodolites made by the instrument department of the Survey, which have horizontal circles graduated to 5′ spaces and are read by micrometer microscopes to single seconds.

The telescope of the theodolite has two parallel vertical wires, about 20″ apart, for making pointings for horizontal angles. The results from a number of seasons' work indicate that this arrangement of wires is more satisfactory than either the single vertical wire or the oblique cross. The double wire is especially effective when the image of the light or heliotrope is large and unsteady.

In making measurements of horizontal directions each direction in the main scheme was measured 16 times. A direct and reverse reading was considered one measurement, and 16 positions of the circle were used.

When a broken series was observed, the missing signals were observed later in connection with the chosen initial station or with some other one, and only one, of the stations already observed in that series. With this system of observing no local adjustment was necessary. Little time was spent in waiting for the doubtful signal to show. If it was not showing, say within 1 min. of when wanted, the observer passed to the next. A saving of time results from observing many or all of the signals in each series, provided there are no long waits for signals to show, but not otherwise.

A much greater portion of the observing was done at night. On this arc there were 24 primary directions on which all the observations were made during the day, and there were 159 directions on which all the observations were made at night. For each group of directions the average correction to a direction was 0.25″, which indicates that day and night observations have equal accuracy; but owing to the limited number of directions observed by daylight only this evidence should not be considered conclusive.

The limit of rejection of observations upon directions in the main scheme was 5″ from the mean. No observation with the mean within this limit was rejected unless the rejection was made at the time of making the observation and for some other reason than because the residual was large. A new observation was substituted for the rejected one before leaving the station, if possible, without much delay.

The average closing error of a single triangle for the 183 triangles of this arc measurement is 0.90″. There are only two triangles with closing errors greater than 3.00.″ Although the party on the Texas-California arc of primary triangulation was not striving for extreme accuracy at the expense of progress, the average accuracy shown by the triangle closures is greater than that for the other great arcs of the United States, the transcontinental triangulation, the eastern oblique arc, and the 98th meridian, the average triangle closing errors of which were, 1.06″, 1.19″ and 0.92″, respectively.

**A New Form of Insurance** was mentioned in a recent issue of the London "Electrician," where note was made of a company lately started in London for insuring inventors and investors against losses through worthlessness of patents and through infringements. A large amount of preliminary investigation was necessary, before the policy terms and rates could be fixed. The plan has been tried and found satisfactory, of making preliminary investigation of all propositions on which insurance was asked, making a nominal charge for those that proved unsound, and making no charge where the project was found to be all right and insurance was taken out on it.

## Roman Concrete Work

A review of practice in the construction of Roman buildings and other structures of concrete has recently been published by E. B. Van Deman in the *American Journal of Archaeology* (April and July, 1912). The primary object of the review is to bring out the essential characteristics by which structures of the different periods may be identified and distinguished. It enables us, however, to abstract a short summary, unfortunately very inadequate, of some essential features of Roman concrete construction as found by the author in the examination of most or all the concrete buildings belonging in the ten centuries from about 750 B. C. to about 300 A. D.

STONE MASONRY AND CONCRETE—In the earliest times the more important buildings were constructed of stone masonry, usually squared stone laid dry; unbaked brick was the material for common construction. Gray tufa, found extensively in Rome, was used almost exclusively in the early stonework, but later other stones, domestic and foreign, were employed.

Until the second century B. C. concrete apparently was not in use. Somewhat before 100 B. C., some monumental structures containing concrete were erected, indicating no doubt that concrete had come into use a little before this period. Concrete construction increased in extent of use from then on, with considerable variation, however, in its make-up and in the nature of the facing (in no period was concrete used without facing to any extent except in foundations and other invisible parts of buildings). Roughly at the beginning of the Christian era it reached the position of dominant material (or mode) of construction.

Throughout the entire Roman period, concrete was made of lime and puzzolana (with admixture in some periods of a little neutral sand or gravel), and, as aggregate, a considerable range of material—stone, brick, and broken tile. In general, the aggregate used may be said to have been old material, i.e. building débris, in all periods. Thus the nature of the concrete of any given period was in a large part determined by the kind of stone (or other débris) available from older structures.

As already mentioned, the earliest stonework was built largely of gray tufa found in the city. In the second century B. C. travertine and peperino were introduced, and used quite extensively, and for more luxurious facings some marble was employed. A century later these materials had become differentiated as to use, to the extent of having the stronger stone concentrated at points of special loading and the like. Still later, a harder stone, selce, came into use. While the earliest stonework was laid up dry, at this time it was common to have stone bedded in mortar, although dry masonry seems to have continued in use for a long time.

In this time—during Julius Cæsar's reign—concrete became quite common for foundations and massive parts of masonry buildings, and some structures of this period are found which are wholly of concrete (with, however, the stone at the face laid or set, rather than deposited irregularly). Under Augustus concrete construction became practically universal, being used for foundations and massive parts of structures, for the cores of walls, etc., but in the case of walls nearly always with facing except in very minor buildings and parts of buildings. The period after this was largely a period of development and change in brick and tile facing, as well as also in the character of the concrete. Broken tile and brick are first found as a concrete aggregate in the period of Augustus, and after Nero they are found abundantly, giving the impression that all available building débris was used, from brickbats to marble fragments.

CHARACTER OF MORTAR—The concrete mortar used in the first and second centuries B. C. was composed of gray to gray-brown puzzolanic sand with a poorly burned lime rather deficient in quantity, producing a friable mortar of gray color. The mortar of later years is found to be cleaner, stronger, and less friable. Under Julius Cæsar, a reddish puzzolana was brought into use; a better variety of this became the standard mortar material in the time of Augustus, a clean red puzzolana which gives a quite characteristic color to the concrete of that period. Similar puzzolanic material was used continuously (except for the use of inferior gray puzzolana in the time of Nero), reaching its highest quality in the periods of Trajan and Hadrian. The mortar of this latter period is clean, very compact, of white and red color, and almost flintlike in hardness; the lime is clean, and the puzzolana (red) is free from all trace of earthiness. Later, the practice in point of mortar quality again deteriorated somewhat; the mortar of monuments dating from Maxentius and Constantine is described as considerably less firm and tenacious, of variable color (generally reddish), with lime of but medium quality, though fairly rich in quantity, and the general character of the mixture irregular and poor.

SIZE AND ARRANGEMENT OF AGGREGATE—In the earliest concrete structures the pieces of stone (tufa) employed were very large, the maximum dimension often exceeding a foot. Aggregate that may be described as large continued in use for several centuries, and until broken tiles (in large pieces) begin to appear (about the time of Augustus). No statement is made concerning the size of aggregate in the later centuries, but with the general use of diversified débris the sizes no doubt became smaller.

The earliest concrete appears to show no regularity or arrangement of the stone in the concrete whatever. When broken tiles were first used as aggregate, they were laid somewhat irregularly but closely packed in rows. Laying the bricks or brickbats or pieces of roof tile in irregular rows appears to have been practiced more or less extensively in the centuries following this also, as remarks made about various periods between Augustus and Constantine describe the broken brick as being "laid in irregular rows," "laid flat in rows," "in closely packed rows," etc. The use of bonding courses of large floor-tile in walls (at least in brick-faced and tile-faced walls) at fairly regular vertical intervals also points to some regularity in the laying up of the concrete material.

FACING OF CONCRETE WALLS—The use of concrete in exterior walls came into adoption much more slowly than its use for interior walls. At first the concrete was only a filler, the stone outside portions of the wall being depended on for strength. Soon, however, the stone part became thinner, and the concrete core was made the structural element. Facing, nevertheless, continued to be used either universally or nearly so. About the time of Julius Cæsar a facing of small stones or tesserae, 2 to 2½ in. (and later up to 4 in.) in size, was introduced (reticular facing), and this long retained its popularity and, indeed, never fell wholly into disuse.

In the same time facing of brick, or cut (the author says "sawed") roofing tile, became common. This type later found exceedingly wide use; both brick specially made for the purpose (triangular brick) and brick made out of old brick or tile by cutting, formed the material for such facing. Facing of cut tile, laid flat in regular coursing like brickwork, was very often accompanied by the use of tile shards as aggregate in the interior concrete; this points to the influence exerted over the character and concrete methods of construction by the nature of the available refuse.

Facing of triangular brick came into use about 50 A. D. The convenience of this material appears to have been largely responsible for developing wall construction to the point where brick-faced concrete was the standard type. A century later, cut roof tile again came into use for facing, being then employed even for decorative parts of important public monuments—in a time when concrete construction was almost universal and was used in all types of buildings; but in the following century and thereafter triangular brick prevailed again. In the time of Septimius Severus the brick had decreased down to a little over 1-in. thickness, as compared with nearly 2-in. thickness in the early period of brick facing.

## A Novel Type of Cantilever Foundation

A cantilever foundation of a novel type has recently been devised for two buildings in New York City, one a 12-story loft building at 25-29 West 31st St., and the other a 12-story apartment house at 141st St. and Riverside Drive. We give below a short description of the construction in the case of the loft building; the apartment-house construction was of a similar nature and by the same engineer, and is not given here.

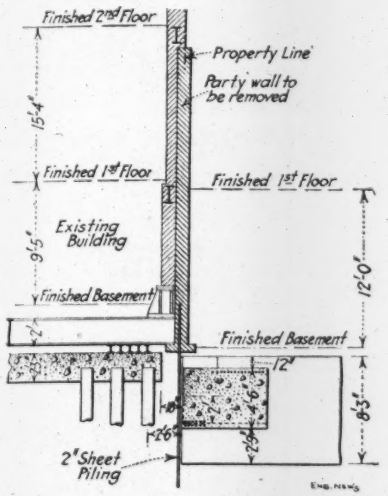


FIG. 1. SECTION THROUGH PARTY WALL, SHOWING PILE FOOTINGS ON EXISTING BUILDING AND CONCRETE CANTILEVER FOOTINGS ON NEW BUILDING

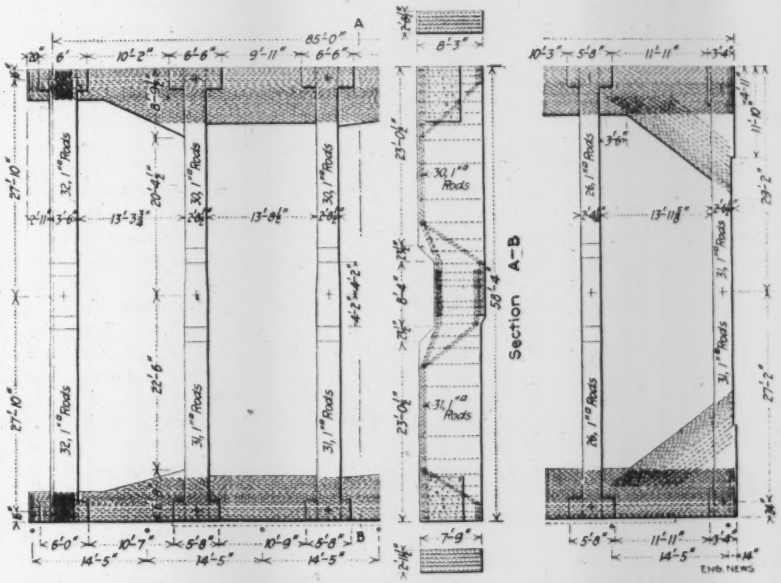


FIG. 2. PLAN OF CONCRETE CANTILEVER FOOTINGS OF 12-STORY LOFT BUILDING 25-29 W. 31 ST., NEW YORK CITY

Fig. 1 represents a sectional elevation through the portion of the lot adjacent to the next building. On this property it was found impossible to reach the rock with open caissons, and as the adjoining building is resting on wooden piles installed some 15 years ago, it was necessary to devise some kind of foundation by which the adjoining building would not be disturbed. Inasmuch as the water level in this section of the town has been lowered considerably in the last few years, the engineer had some fear that the wooden piles would not be in good condition, and therefore he did not care to undertake any deep foundation construction which would require underpinning of the old building. The design which he decided upon is shown in plan in Fig. 2 and in several detailed sections in Fig. 3.

In effect, it consists of carrying the three lines of columns, that is, the two outside and a center line, on concrete beams founded on earth bottom and so interconnected as to make the whole foundation a complete frame over which the entire load would be distributed. This idea worked out into a design by which each transverse line of columns was carried on a transverse concrete beam, which tied at the sides into a much heavier beam running lengthwise of the building. The special feature of the cantilever construction is that the one cross-beam and a portion of each longitudinal beam form a T-section, the center of gravity of which is the same as the center of gravity of the column loads plus the weight of the sidewall. Thus, looking at Fig. 2, it will be seen that half of the load coming on the column in the center of the building and the whole load coming on a wall column and the wall load adjacent to that column is carried on that portion of the side concrete beam and the cross-beam there shown, and that the center of gravity of these loads is the same as the center of gravity of the T-beam formed by the side beam with the transverse beam going at right angles from it. The variation in the loads and, consequently, in the centers of gravity, resulted in different shapes and sizes of the supporting beams.

This foundation was designed for a pressure of 4 tons per sq.ft., reducing in proportion to the live and dead load in figuring dead load only. The pressure underneath the footing is absolutely uniform on account of the distribution of loading above. All beams were reinforced as shown in the drawings with twisted-steel rods. The whole footing was installed within two weeks at a very low cost for a building of this character, and the adjoining building, which was watched very closely during construction, showed no settlement of any kind.

This design in the two buildings was made and the construction carried on under the direction of C. J. Jeppesen, Consulting Engineer, New York City, to whom we are indebted for this information and the drawings.

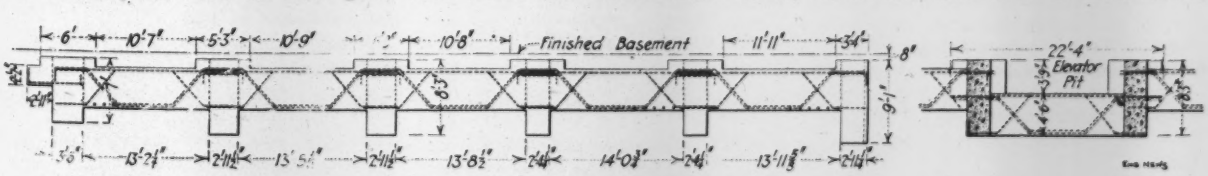


FIG. 3. DETAILS OF CONCRETE FOOTING BEAMS

**Ploughing by Explosives** is to be undertaken on an experimental farm of the Cornish County Council, in England, according to "The Engineer." A number of trials have been made in cracking and pulverizing the sub-soil by exploding cartridges of gelignite, and the resulting condition of the soil has been most promising. Similar tests conducted in this country have produced equally favorable results.

# A Symposium on Ventilation

By D. D. Kimball, Prof. C.-E. A. Winslow, Dr. Y. Henderson and Prof. F. S. Lee.

**The ventilation problem, or why we should ventilate, is the main thesis of these papers. Mr. Kimball, whose paper is given first, ranges over a broader field and goes more into the details of ventilating practice and air conditioning generally than do the other three authors. Professor Winslow treats of ventilation from its physiological and some of its practical aspects. He views it as largely a matter of controlling temperature and humidity, going further in this direction than does Mr. Kimball. The paper by Dr. Henderson deals wholly with the ill effects of bad ventilation on the individual. Prof. Lee's paper was on the broad general subject of temperature and humidity as related to fatigue, but has been included here because of its bearing upon ventilation. The papers by Dr. Henderson and Prof. Lee tend to justify Prof. Winslow in urging that ventilation aims be placed on a new basis.**

*Papers presented to the International Congress on Hygiene and Demography, Washington, D. C., September, 1912. The first two papers are given in full; the last two in brief abstract, only. The papers by Mr. Kimball and Prof. Winslow were read before the section on State and Municipal Hygiene; the one by Dr. Henderson before the section on Hygienic Physiology; and the one by Prof. Lee before the section on Hygiene of Occupations.

## The Present Status of Ventilation

By D. D. Kimball*

Ventilation, until recently secure in its position before the public, may now be said to be without definite or satisfactory status. Present standards are attacked and declared unscientific, the methods of ventilating engineers are condemned and, by some, artificial ventilation of schools, hospitals, and similar buildings is said to be entirely unnecessary.

It may be that not all of the principles or methods of ventilation accepted in the past or at the present time are correct, but if the best of them are in error, the fact has not been scientifically demonstrated nor have better methods been exemplified.

It may be successfully maintained that ventilation as now practiced has accomplished much and should be continued until better methods are developed and proven to be correct. (See "Ventilation and Public Health," *Annals of American Academy of Political and Social Science*, March, 1911.) Without a doubt lack of ventilation and inefficient ventilation result in a constant loss of human life and of actual money which, if correctly computed, would be appalling. This is adequate justification for the greatest urgency in carrying on investigations and tests and for such meetings as the one of this afternoon.

Much doubt and misapprehension regarding the worth of ventilation is being aroused by statements which are being made derogatory to ventilation, these statements being based upon lack of investigation and unscientific or incorrect data. This is doing incalculable injury to the cause of ventilation and to the best interests of mankind.

By many investigators the ventilation problem is approached as though it had but a single element of importance, as for instance, air volume, air quality, temperature, humidity or air movement. By others two or three of these elements are viewed as essential, while by still others the problem of ventilation is viewed as a problem having several sides of perhaps equal, or at least great, importance and other sides of less importance. To the author the latter view seems the correct one.

The ventilation problem will here be considered under the following headings:

(1) Chemical composition of air; with special reference to oxygen, ozone, carbon dioxide; and investigations of those elements in the air to which but little thought is now given.
(2) Organic matter, i.e., that due to exhalations and body excretions.
(3) Dust.
(4) Humidity.
(5) Temperature; optimum, effect of high, low and varying.
(6) Air volume; for different classes of people, different surroundings of same, and as effected by different systems of ventilation, different chemical and physical qualities, or different degrees of diffusion.
(7) Air movements; still, moving (below the point of sensible drafts) drafts, breezes.
(8) Heating of air; is it, whether containing or free from dust, injured by heating? Relative effects of high and low temperature heating surfaces.
(9) Cooling.
(10) Recirculation.
(11) Relation of ventilation to conditions of rest, sleep, normal activity and violent exercise, and ventilation as affected by age, sex, climate, etc.
(12) Methods of determining the effect of ventilation and its elements upon the individual and masses of people.
(13) Natural versus artificial ventilation.
(14) Efficiency of installation and operation.

*Of Richard D. Kimball Co., Consulting Engineering, 15 W. 38th St., New York City.

It would seem necessary that the air should be properly conditioned before considering the method of its use, just as a surgeon looks to the condition of his instruments before undertaking his task. Not that air conditioning is necessarily the most important question involved, but good ventilation can only be possible when good air is the basis thereof, and no manipulation of air volume, movement, or temperature of foul or improperly conditioned air may be made a substitute for good air. It is admitted that poor aërial surroundings may be improved by a stirring of the poor air, but this does not constitute good ventilation. As stated by Prof. Affleck, in "The Ventilation of Gymnasia" (*American Physical Education Review*, April, 1912) "* * * as far as experimental conditions are concerned the chemical composition of the expired air does not produce an injurious effect upon the human system, but the writer has yet to learn of extended observations which prove that continuous living in such vitiated air does not impair health."

The designing engineer has, in the past, paid too little attention to the quality of the air used for ventilation or to its source.

(1) Chemical Composition—Referring to the chemical composition of the air, oxygen is generally considered the most important element. Normal air contains approximately 21% of oxygen; exhaled it contains still about 16%, the 5% difference in oxygen having been replaced by carbon dioxide, water vapor and tissue excretions. It is stated by the physician and biologist that no good is accomplished by increasing the proportion of oxygen beyond the 21%, even in cases of pneumonia, and that we could continue to exist indefinitely in air containing 16% oxygen, but no claim may be made that air containing 21% oxygen and free from the elements with which it is laden upon exhalation is not better than the air containing 16% oxygen and 5% of injected undesirables.

Carbon dioxide, once considered a poison, is now considered negligible so far as its effect upon health is concerned, but we may not neglect its value as a means of determining air quality for, although not necessarily harmful in itself, it is a fact that large proportions of carbon dioxide usually indicate decreased proportions of oxygen, or the presence of carbon dioxide produced by the distillation of dust.

Ozone, only recently linked with the question of ventilation, is worthy of serious consideration. It has proven an efficient ally to the physicians in cases of pneumonia and other diseases and its value as a sterilizing and oxidizing agent is generally recognized. Practically no use is now being made by engineers of ozone as an adjunct to ventilation, although a limited amount of experimentation is underway to determine its worth. The cost of installing and operating ozone machines is relatively so small in comparison to the cost of install-

ing or operating the ventilation plant (probably not over 2 to 4%) that cost should prove no obstacle if its efficacy is demonstrated. Its use in connection with the ventilation of the English Parliament Buildings is said to have been advocated by Dr. Leonard Hill. That it is striking the popular imagination is evidenced by its use in some of our theaters and by the many small ozoning devices coming into the market. However, this use is without scientific basis or measure. Slightly noticeable at times in the country or on sea it is practically lacking from the air of the city, due probably to its absorption in the process of oxidization of wastes of the city streets, and the presence of factories and power plants.

It is found in the proportion of about one part to a million in country and sea air, while practically missing in the air of the city. May it not be possible to improve the air of our habitations in the city by a restoration of that amount of ozone found in the country or sea air, if it it may be done by means of apparatus which will not also produce nitrous oxides or other harmful products?

Dr. G. Lennox Curtis, who has experimented largely in this field, asks, "if ozone is the active principle of oxygen and the atmosphere of cities contains only a small percentage of it, why not supply it by means of the electric coil or ozone generator?"

It is possible that there are other constituents of the air of importance of which but little is known, as for instance argon.

(2) ORGANIC MATTER—The problem of organic matter in the air of an occupied apartment is still in debate. Brown-Sequard and others proved to their satisfaction that such matter exists. Haldane, Smith, Lehman and others proved to the satisfaction of themselves and others that such was not the case. Prof. Rosenau, as the result of recent experimenting, concludes that there is justification for the belief in the existence of organic matter, specific in nature, in expired air. Analysis of his experiments may lead the physician and biologist to question the correctness of his conclusions, but so direct a bearing has this question on the all important question of air renewal that the earliest possible determination of the problem is urged.

(3) DUST—The dust problem, as it relates to ventilation, is too lightly considered. It is more than an annoyance, for it involves physical, biological and chemical phases. Breathed into the respiratory tract it may cause not only annoyance but irritation or even abrasions which, in the opinion of many, increase the liability to communication of disease. The germ-bearing possibilities of dust are strongly urged by some authorities and denied by others, the same situation existing in the matter of communicability of disease through the means of germ-laden dust and air.

Tests by Prof. V. Esmarch and Nussbaum are quoted as evidence of a chemical change of the air due to the decompositon of organic matter when coming into contact with heating surfaces of high temperature, ammonia being found in noticeable quantities by both experimenters, while others have maintained that carbon monoxide is produced. Objectionable odors are said to be due to this cause, and the air is said to be robbed of ozone which has been utilized in the process of oxidation.

Conrad Meier, an eminent ventilating engineer, as the result of study and observation, in a paper on the subject asserts that the dust problem is the most important one in the general problem of ventilation, far more important than the question of humidity; indeed he states that most of the complaint charged to extremely dry air is due to the effect of dust.

Relatively few ventilating systems include air filters, and the majority of the filters used are of the cloth variety, the cloth often being too small in area and of small merit as a filtering medium, mounted on poorly constructed and leaky frames. In a fan system of ventilation the velocity of the air through the cloth should not exceed 40 ft. per minute. The use of the air-washing filter, which is much superior, has been limited, because, like many other desirable adjuncts to a complete ventilating system, it is too often proscribed on the ground of cost, although the average cost of the cloth filter is about 2 to 4%, and that of the air washer but 4 to 7% of the cost of the heating and ventilating system.

(4) HUMIDITY is another much debated question. There are those, like Mr. Meier and Prof. Woodbridge, who decry the importance of artificial humidification, who see no ill effect in breathing dry air, and who place no faith in what seems to be justifiably said to be the ill effects of dry air. On the other hand, Dr. Henry Mitchell Smith, Prof. Hough, Dr. Wilson and others maintain that excessively dry air results in the enlargement of gland tissues and the thickening of the membrane of the respiratory tract, the productions of feverish and parched tongue, lips and skin, the causing of the eyes to redden and smart, the ears to become dried, the aggravation of catarrhal conditions extending even into the eustachian tubes. Headaches are said to result, the vitality is said to be lessened, and the dry air is regarded as an excitant, causing sleeplessness and irritability. In a plant coming under the notice of the author just these complaints are made whenever, in cold weather, the humidifying system becomes inoperative.

Conversely the authorities last named above assert that moist air feels balmy and has a soothing or depressive effect which tends to produce restfulness and sleep.

The effects upon our health and comfort of moisture in the air as it acts through the respiratory tract and on the outer surface of the body should be determined with more exactness.

As to the desirable degree of humidity there seems to be little agreement among engineers or physicians, but 30% minimum and 80% maximum are the extreme limits mentioned. In artificial humidification it is the practice of our designing engineers to provide for a maximum of 50%, this being regarded as sufficient to maintain healthful conditions, while 35% is used as a minimum in extreme cold weather to provide against condensation on outside walls and on windows, and because it is believed that no harm will result at this minimum. It may be that this lower range is too low, but it has yet to be proven, and this is not below a condition sometimes found in outside air.

The humidity within our homes, schools, hospitals, offices, stores, and factories will frequently be found to be below 20% and sometimes as low as 12%, much less than on the driest desert known. Opening of the windows will not remedy this condition without lowering the temperature, for the warming by the radiators of the air thus admitted increases its capacity for moisture, that is, reduces its relative humidity.

That humidifying devices are not more used is less the fault of the designing engineer than of the owners and architects, who will not authorize the necessary expenditure. The cost of such devices is not great. Evaporating pans with steam coils and automatic humidity regulation will usually cost less than $400 for 15,000 cu.ft. of air per minute, or about 3 to 5% of the cost of the heating and ventilating system. Humidifying devices with automatic regulation added to the air washer involve no greater cost, and this is the better arrangement, as it provides for dust elimination also.

The cost of operating the humidifying system may not be neglected. It requires approximately four times as much coal to evaporate the water necessary to raise the inside relative humidity to 50% on a zero day as may be saved by lowering the room temperature from 70° to 60° F. But there is no question in the mind of the author that artificial humidification is most important and worth more than its cost.

(5) TEMPERATURE (and humidity) are urged as the most important elements of ventilation, especially by Winslow, Benedict, Evans, Crowder and others. The author believes that they are very important, but believes also that their relative importance is too greatly magnified in view of the limited data of conclusive nature available.

Seventy degrees was for long accepted

as the desirable temperature in this country, although 68° is now the standard generally used by engineers. In England, 60° is generally adopted, although there is said to be a growing tendency toward a higher temperature there. Experiments are being conducted in Boston and New York schools and elsewhere to determine the possibility of reducing the temperature to 65° or even 60°, and to determine the relation of humidity and temperature to the health of the pupils.

As is well known, excessively high temperatures, especially when associated with high humidity, place upon the temperature-regulating system of the body a severe tax. It is generally agreed that the critical point of comfort is 72° wet-bulb temperature, a fact which is the basis of much of the argument for replacing the dry-bulb with the wet-bulb thermometer, the wisdom of which is disputed by J. J. Lyle.

It is urged by Dr. Gulick, Dr. Thompson and others that a varying temperature is desirable. That low temperatures have a therapeutic value is common knowledge, and we are all subject to, and doubtless helped by, nature's varying temperature. But during period of sedentary occupation with the usual clothing a uniform temperature is required. A combination of periods of uniform temperature during periods of quiet with a lowering temperature and a "flushing out" of the room during short periods of exercise is unquestionably good, even if not scientifically demonstrated. The manipulation of the ventilating system will vary the temperature, or the windows may be better used for this purpose.

The temperature of a densely occupied apartment is directly affected by the occupants thereof, method of illumination, adjoining buildings and exposure. For the proper regulation of room temperature the heating and ventilation should be the functions of separate portions of the apparatus, that is, direct radiators should be used for heating to the extent of balancing the heat exchange through exterior walls, windows and outside doors, and indirect radiation should be used for heating the air used for ventilation. The units of direct radiation should be small and generally distributed to prevent concentration of heat areas and to promote quick heating and cooling of radiators.

With the problem of air conditioning solved, the question of methods of ventilation, air standards, etc., would be greatly simplified.

(6) AIR VOLUME—The standards of air volumes now in use by engineers are arbitrary and are too little modified in practice by engineers to cover the varying conditions above mentioned, being based upon the maintenance of certain $CO_2$ standards. The air quantities generally used in practice are 30 cu.ft. per minute per occupant in schools, 15 to 30 in theaters, churches and auditoriums, factories and mercantile establishments, 60 to 100 in hospitals and dwellings, and 100 to 200 in surgical and contagious hospitals.

These quantities have been used in connection with ventilating systems operating on the dilution principle, i.e., the air is admitted above the breathing line and exhausted at the floor. There is a growing agitation in favor of the displacement method of ventilation, in which the air is admitted near or through the floor and exhausted at the ceiling, on the theory that the natural course of the air about the body and that exhaled is upward because of its higher temperature and its greatest vapor content. The author believes this theory to be far from proven, but of sufficient importance to warrant careful study. If the theory be correct it may have a most important bearing upon the quantity of air required for ventilation.

Upward ventilation seems to be gaining adherents, but in most cases they are rabidly partisan and they neglect what may be governing conditions, such as details of building construction, possibility of difficulty in the proper diffusion of the air, or the much more important matter of temperature as effected by the heat of the people and lights.

Frequently the practicing engineer finds the heating effect of the occupants and lights of an auditorium sufficient to warm 30 cu.ft. of air per minute per occupant 10 to 12 and even 15°. In such cases, if it is desired to maintain 65° in the room the air must be admitted at 50 to 55° temperature. This may not be done without endangering the comfort, and even the health of the occupants, for to secure proper distribution the air must be admitted in the immediate vicinity of the occupant, i.e., under the seats. When admitting the air through the ceiling and exhausting through the floor the air gradually takes up this heat increment and passes over the body at a comfortable temperature. Incidentally it strikes the head while cool, and passes over the feet warmer, which is physiologically better than the reverse course. With 30 cu.ft. the downward method has been found satisfactory. Any attempt to lessen the volume of air by the use of the upward method in such cases will involve further difficulty in the matter of temperature. A system which may be reversed, being downward in cold weather and upward in hot weather (to carry off the heat) is successfully used.

While these remarks as to the direction of air movement apply especially to auditorium ventilation, this same difficulty may be encountered to a less degree in attempting the upward method of ventilation of school rooms, and this condition will be aggravated in the case of rooms subjected to the heating effects of the sun, which heat must be counterbalanced or absorbed by the air used for ventilation, the air being brought into the room enough below the desired room temperature to asorb the heat given off by the occupants and the excess heat communicated to the room by the sun.

It is the author's opinion that diffusion of air introduced and exhausted for ventilation has been given altogether too little consideration.

It is customary practice among engineers to use one inlet and one outlet to ventilate a school room or a court room, etc., and too often this is applied to a hospital ward and other ventilation work. It is very difficult, and often impossible, to secure an even diffusion of air under these conditions in a room as large as a standard school room. Thus stagnant areas may occur and the ventilating system is then condemned. The location of ventilating flues is always troublesome in the design of the ventilating system for a new building. The architect often finds it difficult or is sometimes unwilling to provide sufficient or suitably located spaces, or money is not made available for their construction. Manifestly a change from the single inlet and single exhaust to multiple openings, properly proportioned and placed, through which moves the same amount of air, will assure a diffusion and efficiency, prevent stagnant areas and thus have a direct bearing on the volume of air required.

Air quality also must possess a direct relation to air volumes, for it is inconceivable that a certain amount of poor or improperly conditioned air will do the same ventilating work as the same amount of air of the best quality.

(7) AIR MOVEMENT, as emphasized by Hill and others as a relief for too hot or humid conditions, is a welcome adjunct to ventilation, but as a substitute therefor it is not to be considered. It doubtless accomplishes a desirable end in removing the body envelope of hot moist air and the exhaled air from the breathing zone, but the air thus removed should be replaced with pure air of a proper temperature and humidity. The air movement produced by a ventilating system should and will accomplish this end without drafts.

Drafts, which would include air velocities from the point where they become sensible to the point of a breeze, are objectionable, but air movement below the limit of a sensible current is essential, otherwise the air becomes stagnant and there is no removal of the heat and moisture of the body envelope. Outdoor breezes which bathe the entire body (assuming proper clothing) are healthful, but breezes never will be acceptable indoors during the winter.

(8) AIR HEATING—Dr. Thompson and others state that air passed through the ventilating system is robbed of its "freshness." It is possible that such observations are due to the generation of am-

monia, and possibly carbon monoxide, from dust in the air coming into contact with heating surfaces of excessively high temperatures. With the dust eliminated it is not believed that air is robbed of anything when brought into contact with heating surfaces of moderate temperatures, i.e., not in excess of 215°, the air not to be heated in excess of 100°, preferably 80 to 90°. Indeed, with dust eliminated, there is no scientific basis for the assertion that the air is robbed in any way by being brought into contact with surfaces at a higher temperature. Chemical and physiological tests along this line are desirable.

In the belief that the temperature to which the air should be heated should be as low as possible, the majority of engineers now use direct radiators in the rooms to overcome heat losses through walls and windows, while heating the air supplied by the ventilating system to a temperature but little in excess of the room temperature, the excess being designed to make up for loss of temperature in transmission. The "blast" system of heating and ventilating, in which all of the heating was done by means of blast coils which heated the air to 125° or even 150°, is now but little used in schools, hospitals or similar buildings.

(9) AIR COOLING—In the field of air cooling but relatively little has been done, largely because of the cost of installing and operating the apparatus, for a positive method of cooling involves the use of refrigerating apparatus.

It is suggested that the heating or ventilating system may in part be used for this purpose and that there is no more reason why we should heat our apartments in winter than cool them in summer. A very limited amount of creditable work has been done in the cooling of banking rooms and hospital wards, in which the same fans and fan coils are used for heating and cooling, steam being used in the coils in winter and brine in summer. Usually a cooling effect of 10° in extreme hot weather is the maximum desired.

In one case the removal of a cooling system which cost a very large sum is contemplated not because the desired temperature and relative humidity was not maintained with any outside weather conditions, but because the effect of the cooled wards was not believed to be of as much value clinically as the free use of the sea air through open windows. Observations were made during the operation of the cooling plant on the patients and on the nurses, records being made every 15 min. in the case of the nurses from whom complaints of headaches were frequent.

It may be that the real cause of complaint was the fact that a 70° temperature and 50% relative humidity was maintained at all times and that the difference between inside and outside conditions were too great for the comfort of the nurses subjected to both natural and artificial conditions. Also the hospital was unusually located so that it received sea breezes throughout at all times.

The cost of installing the cooling plant is large. In a recent case involving the supplying of 20,000 cu.ft. of air per minute (not a large installation) the increase in size of the refrigerating plant involved $6000 of additional expense, while had a plant been installed especially for this purpose the cost would have been double this amount.

It is difficult to make a definite statement regarding the cost of operating an air-cooling plant. If exhaust steam, otherwise unused, is available the cost of fuel may be eliminated by the use of an absorption refrigerating plant. If the water required for cooling in the refrigerating plant may be used in the boilers and plumbing system another large expense is also eliminated. The cost of service, the remaining important item of expense, depends upon the size of the power plant of which this is a part. The other incidental expenses are small.

If exhaust steam is not available, or the water used by the refrigerating plant for cooling may not be used as suggested, the cost of operating the air-cooling plant becomes serious. In such a case, it may be generally stated that the cost of cooling a building 10° is approximately equal to the cost of warming it to 70° in zero weather.

(10) RECIRCULATION—It is only recently that the idea has been conceived of recirculating the air used for ventilation. At the International Y. M. C. A. College, Springfield, Mass., some most interesting experiments have been made along this line by Dr. McCurdy and Prof. Affleck (see *American Physician Educational Review*, June, 1912.)

It was found that so long as the same air (except effected by natural leakage) was used and was passed through the air washer in operation, the conditions in the room were entirely satisfactory to the men exercising in the room, but when the washer was not in operation conditions immediately became objectionable and odors were noticeable. The effect of the recirculated air upon the men was no different, so far as could be felt or observed, from the effect of the air when taken directly from outside. In these same tests interesting data were obtained regarding the effect of varying temperatures and humidities. Additional tests and experiments along this line are to be made during the coming winter.

(11) CONDITION OF OCCUPANTS OF ROOM—It is difficult to say how much attention is given by engineers to the varying demands on ventilation as affected by conditions of the occupants, such as rest, sleep, normal activity, mild or violent exercise, to the questions of age, sex, conditions of health, cleanliness of occupants, or to the effect of the illuminant used. Possibly the data are more advanced than the practice, but additional data for these various conditions are desirable, both as to heat and moisture elimination and air quantities required.

(12) EFFECTS OF GOOD AND BAD VENTILATION—So far as known to the author there is no agreement as to a satisfactory method of determining the effect of ventilation or the effect of its lack. The psychological element makes necessary that the subjects of the experiment should not be acquainted with the fact that they are under experiment except under unusual circumstances. There are so many variables in ventilation that it is necessary to make long continued experiments under each condition upon a large number of subjects, with carefully prepared records covering all the necessary physical details, such as health, surroundings and general progress of the subjects; also records of the temperatures, humidity, and air quality and quantities involved.

(13) NATURAL AND ARTIFICIAL VENTILATION—A great furore is being made by the advocates of natural (window) ventilation, especially for schools and hospipitals, the elimination of artificial ventilation for such buildings being urged. It may not be inappropriate to refer to the appeal made to the American Society of Heating and Ventilating Engineers in January of this year that it should undertake a movement to bring about the elimination of artificial ventilation from school buildings. It seems to be forgotten by the advocates of natural ventilation that artificial ventilation of schools was developed more than 40 years ago, largely because of the failure of natural ventilation.

There would seem to be a serious lack of perception on the part of those who class together schools and hospitals in this crusade, for the conditions are radically different in the two classes of buildings. The usual hospital ward has windows on two or three sides, well exposed to the wind, the patients are under the special care of nurses and the space per capita is large. In the case of the modern school the unilateral system of lighting prevails, so that there are openings upon but one side of the room, the pupils are variously clothed and the space per capita is less than one-fourth of that in the hospital. The wind can serve the rooms of but one, or never more than two sides of the school building and the side served by the wind varies frequently. What do the advocates of exclusively natural ventilation propose for the rooms upon the remaining two or three sides of the building?

There is no question that natural ventilation should be used just as often and just so far as it can be employed without endangering the health and comfort of

the room's occupants. The ventilating system as now designed by the best engineers is not "unbalanced" by the opening of windows and doors, so that conflict between the natural and artificial systems is avoided.

For all densely occupied buildings, such as schools, most hospitals, libraries, churches, theaters, auditoriums, mercantile establishments, factories, etc., natural ventilation is insufficient during much of the heating season and a system of artificial ventilation is essential to the comfort, health and efficiency of the occupants of the building. Also the degree of efficiency with which the building serves the purpose for which it was built is directly increased by the ventilating system. Some of the buildings of the classes mentioned manifestly require artificial ventilation whenever occupied, the others during inclement weather and when, as frequently is the case, the lack of a breeze brings about the most serious failure of natural ventilation. Also artificial ventilation is necessary for those sides of a building not exposed to the breeze, for the season of the year when the windows may not in safety be opened, especially in schools, and for night service where ventilation is required during the night in cold weather.

How air filtration, humidification, and the prevention of the so called robbing of the air of its "freshness" by coming into contact with the direct radiators in the room is to be accomplished is not explained by the advocates of natural ventilation, nor have they produced medical, scientific or other practical data substantiating their position.

There is a growing conviction that when the problem of air conditioning and the proper use of the air are mastered the artificial ventilating system will readily demonstrate its usefulness and its superiority over natural ventilation.

(14) EFFICIENCY OF INSTALLATION AND OPERATION—To the practicing engineer the following reasons appear primarily responsible for many of the alleged failures of ventilating systems already installed and for much of the criticisms resulting: lack of skill in designing, a penurious policy on the part of the owner in restricting the funds available, or the purpose of the owner to reduce the cost of fuel, electric current, and labor regardless of its effect in limiting the efficiency of the ventilating system. So long as the owner will decline to pay the extra cost of expert services for the design of the ventilating equipment, leaving what is essentially an engineering matter in the hands of the architects or contractors, so long as he will insist upon more space, more marble, or more gargoyles for the same appropriation in preference to giving adequate heart and lungs to the building, so long as he will employ cheap operating labor, failing to realize that this is most expensive in the end, and so long as he insists on reducing coal, electric and labor bills at the expense of a limitation of the vitalizing air supply of the building, just so long may failures of ventilation systems be anticipated.

If a school board too closely watches the coal pile and taxes the operating and designing engineer for every pound of coal burned, it may not, with justice, hold the teachers responsible for poor results with the students. If low installation and fuel costs are preferred to ruddy cheeks and bright attentive and retentive minds, air filters, humidifiers and even the ventilation system may be dispensed with. The publicity which has been given to the critics and their reference to "sterilized," "roasted," "canned" or "superheated" air, and "air heated to four hundred degrees" (which is impossible in a steam-heating plant) could scarcely fail to promote a disinclination among owners to properly install or operate ventilating systems. A great campaign of education is needed to inform the public of the great value of the fully equipped and properly operated mechanicel ventilating system.

The solution of the problems of ventilation involves much painstaking study, investigation, and experimentation, the co-relating of current experiments and the coöperation of experimenters. It involves physiological and engineering questions, necessitating for its fullest and quickest solution the active coöperation of the medical and engineering professions. A national ventilation commission, adequately financed, would be a most efficient instrument in bringing about these results. This commission should consist of doctors, physiologists, laboratory men, and designing engineers who are experimenting in this field. Its work would be similar to that of the national milk and other similar commissions. By coöperating with investigators, collecting data, comparing results obtained in different cases, suggesting new tests and experiments, publishing information, and finally determining certain standards and methods for ventilation a very great service would be performed for the people of this country. The comfort and welfare of humanity which are so vitally at stake should be sufficient to command to energetic action in the solution of these problems.

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## The New Art of Ventilation: Some Principles which Follow from Recent Physiological Research

BY C.-E. A. WINSLOW*

The art of ventilation was born too soon. Water purification only began to be important after it was learned what the real objects of the process were. The aims of sewage disposal and garbage disposal have always been more or less clear, although emphasis has shifted somewhat as to the relative weight of sanitary and esthetic motives. Ventilation, however, became a vigorous practical art long before there was any real knowledge as to the effects upon the body of the air of confined spaces—that is, before there was any sound conception of what the objects of ventilation were. Tomes were written upon the subject, based on wholly erroneous conceptions as to the dangers from expired air.

First, carbon dioxide was treated as in itself a poisonous and dangerous substance and the chief cause of the sensations experienced in a crowded room. In so recent, and in many respects so excellent, a book as Hoffman and Raber's "Handbook for Heating and Ventilating Engineers" (1910) we read that carbon dioxide "is constantly being diffused throughout the air of the room, thus rendering it unfit for use. If this carbonic acid gas could be disassociated from the rest of the air and expelled from the room without taking large quantities of otherwise pure air with it, the problem of the heating engineer would be simplified, but this cannot be done." The effect of carbon dioxide, however, could easily be tested and was long ago proved to be nil, in any concentrations which could occur under the most extreme conditions of normal occupancy.

Then the mystically minded turned to the organic matter in the air and, aided by Brown-Séquard, whose brilliant but loose experimentation gave currency to so many scientific fallacies, the conception of a subtle and mysterious poison—morbific matter or crowd poison—was evolved. This theory was more intangible and therefore less easy to disprove.

Gradually, however, it was shown by the work of Flügge in Germany, of Haldane and Hill in England, and of Benedict in the United States, that the chemical explanation of the harmfulness of the air of confined spaces was wholly without foundation. When men are shut up in calorimeters all the effects of "vitiated air" can be duplicated by the combined effect of two simple physical factors, heat and moisture, while *vice versa* if the atmosphere be kept cool all the effects of crowd poison disappear, even when over 1% of carbon dioxide be present with all its accompanying morbific matter. The lassitude, depression, headache, dizziness, tendency to nausea, which the susceptible experience in crowded rooms, were all produced at the Hygienic Institute in Breslau by heat and moisture alone. They were not relieved by breathing pure air through a tube. They were relieved by cooling or drying or agitating the air without changing its chemical composition.

The phenomena of increased meta-

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bolism and increased blood pressure which Dr. Gilman Thompson described in the *Heating and Ventilating Magazine* for May as following a change from indoor to outdoor air are familiar physiological results of lowered temperature. In the same paper Dr. Thompson contends that "our present physical means of determining the properties of the air completely fail in recording its most subtle, yet most important, property; namely, that which everyone recognizes for himself, the quality called 'freshness.'" Superheated air conveyed through long metal conduits "is canned air, or roasted air, and has no more 'uplift' for the invalid or growing child than a meal of canned corn for the dyspeptic." The well known doctrine of parsimony in logic, however, forbids us to make two assumptions when one will serve. Anyone who will consult the work of Flügge's pupils and of Haldane, to which full references have been given in an admirable review by Dr. T. R. Crowder, or the more recent work of Leonard Hill, will see that every known physiological effect of "fresh air" has been shown to be due to its physical properties. When new physiological effects are demonstrated to be due to "fresh air" and not to stale air with the same temperature and humidity, it may be necessary to introduce new hypothetical qualities. It is quite clear at present, however, that the principal condition which makes the air of confined spaces uncomfortable and injurious, and really the only condition as to which we have definite scientific knowledge, is excessive temperature and humidity. I am speaking now only of the effects of human occupancy and excluding for the moment the dusts and fumes produced by the combustion of illuminants and by various industrial processes.

The logical conclusion from this premise might at first seem to be that we need not ventilate at all, but might simply cut down heat so as to maintain a low temperature and let air changes take care of themselves. If we could deal only with human beings in a high state of cleanliness this might be the case, though even then air change would offer the most convenient method of keeping cool. Even in the tightly closed sleeping room of a farmhouse in winter, ventilation is practically taking place on a considerable scale through the ceiling and walls and is actually serving to carry away the body heat. Furthermore, under actual working conditions we must deal with human bodies and human clothing as they are; that is, with bodies and clothing which give off considerable quantities of malodorous organic substances. We have no evidence that such odors are injurious to health, but they are offensive to those who enter occupied rooms and for esthetic reasons they should be removed. We must deal with illuminants which discharge carbon monoxide and other more or less poisonous substances and which may have considerable sanitary significance. We must deal in factories with dust and fumes which are highly dangerous and which must certainly be eliminated. Ventilation or air change is generally essential, but the quality of the air supplied is far more important than the quantity. Air conditioning to secure optimum conditions for the working of the living machine, not the removal of supposititious poisonous products, is the prime object of ventilation.

It is no wonder, since the ventilating engineer, until within a year or two, has not had these facts called to his attention, that he has often failed to produce the comfortable conditions at which he aimed. This is the first reason why artificial ventilation has frequently been a failure; but there are two others of almost equal importance. The lack of a proper theoretical basis is primarily the fault of the sanitarian. The second defect in very many ventilating systems comes home more directly to the designing engineer. It lies in faulty construction of ducts and faulty placing of inlets so that a reasonably good distribution of the air forced into the system has not been attained. This has naturally not occurred in the work of the best ventilating engineers, but I think all who are familiar with the art will admit that the distinction between the competent and incompetent has not been clearly drawn in this branch of the engineering profession and that a great deal of poor work has been foisted upon the public. A third reason for disappointment with systems of ventilation comes back to the authorities responsible for their operation. It is useless to design a good ventilating plant and place it in charge of an incompetent janitor. Yet this has been the rule rather than the exception, so far as schools and other public buildings are concerned.

With all these adverse circumstances it is small wonder that general dissatisfaction prevails in regard to the results of so called "artificial ventilation." Hospitals and schools have installed elaborate and costly systems and their occupants, without knowing just what was wrong, have found that they were uncomfortable, hot, stuffy, bad smelling, and have become disgusted with the whole affair.

There is a strong movement today in many quarters to cast aside entirely ventilation by fans and to rely on open windows alone. Hospitals in New York and elsewhere are being built without ventilating systems and vigorous arguments are presented for school buildings built on the same plan. It is useless to ignore this growing body of public opinion or to meet it with arguments as to the theoretical superiority of scientific air conditioning over the casual conditions which we owe to the beneficence of "Nature." It must be answered not by words, but by deeds, by the design and operation of artificial ventilation systems which shall actually produce atmospheric conditions more suitable for the human being than are those provided by nature, as shown by physical tests and corroborated by the sensations of occupants. This means a new art of ventilation based not on the pseudo-sanitation of thirty years ago, but on the accepted results of modern physiology. As a biologist, familiar with some aspects of the science of the human body, and as a sanitarian, called upon to study and report upon the adequacy of ventilating plans and the results of their operation, I want to venture the dangerous task of pointing out what I think must be some of the fundamental principles of this new art.

(1) *Good ventilation involves lowering the temperature of a room by cool air.* The most essential point in ventilation which overshadows all others is the removal of excess heat and moisture. It is clear, then, that any system which does not guard against overheating is bound to fail; and this is precisely where the ordinary system does fail. The usual plan in a school or a factory is to combine direct and indirect heating and to supply fresh air at a temperature above that in the room. The commonest arrangement of inlets and outlets is based on the assumption that air entering at the top will be cooled and will take its exit at the bottom. The incoming air is usually kept at 68° or 70°. When the heat loss through walls is very rapid, all may be well. As soon as the room temperature rises to 70°, however, trouble begins. The direct radiation shuts off at 68° or 70°, but the radiating surfaces remain hot. People and sources of illumination continue to produce heat. The temperature mounts to 72°, 75° and in crowded rooms to 80° or more. Anyone who has regulated a low-temperature incubator knows that it is quite as necessary to have some automatic means of cooling it when it grows too hot as to provide for heating it when it gets too cool. This is where the ordinary heating and ventilating system breaks down. It usually includes efficient methods of quickly supplying heat when the temperature falls, but no methods of quickly removing excess heat when the temperature rises. A system can only be guarded against overheating by supplying air which is considerably cooler than the room temperature to be maintained. With such a condition, when the temperature rises to the point at which thermostats are set and direct radiation is shut off, the cool air may be relied upon to remove excess heat as fast as it is formed.

It will be noted that this principle of cool air-supply implies a separation, in part at least, of the processes of heating and ventilation, such as Dr. W. A. Evans, of Chicago, has so ably urged. In cold

weather a certain amount of the necessary heat may be supplied by heating the incoming air to 55° or 60° or whatever temperature may be adopted. Supplementary direct heating will almost always be necessary, however. I regard it as quite impossible to secure proper temperature regulation without two distinct and independent factors, direct radiation for heating and air for cooling. On the other hand, all this does not necessarily imply artificial ventilation so called. The supply of cool air necessary to remove excess heat may be supplied through windows or through pipes and driven by gravity or by fans.

If we once face the fact that the prime test of a ventilation system is its ability to maintain a low temperature we gain at once a wholly new basis for the calculation of ventilation constants. Instead of figuring our air-supply on the amounts necessary to dilute a given volume of carbon dioxide, we can estimate it on a basis of heat removal. For example, according to Pettenkofer's classic figure, which is a very low one, an adult gives off 400 B.t.u. per hour. Let us assume that this heat must be removed by air entering the room at 60° and leaving it not above 70°. One B.t.u. raises the temperature of about 50 cu.ft. of air by 1° or the temperature of 5 cu.ft. of air from 60° to 70°. Hence our average adult producing 400 B.t.u. will require 2000 cu.ft. of air per hour at 60° to keep the surrounding temperature from rising. An ordinary gas burner produces 300 B.t.u. per cp.hr.; therefore each such burner requires 1500 cu.ft. of air per candlepower. These calculations, of course, ignore direct heat loss through walls and ceiling which with a zero temperature outside may carry off the heat produced by 50 or 100 people. Ventilation provisions must, however, be based on the least, rather than on the most favorable conditions. In crowded auditoria every bit of the 2000 cu.ft. of air is needed and in many industrial processes where the heat produced by human beings and illuminants is reinforced by the friction of machinery and the heat from solder pots, furnaces, mangles, pressing irons, and a host of other sources, even more will be required.

(2) *Heated air should be removed from above and fresh cool air admitted below.* This second principle embodies another of the positions maintained by Dr. Evans, and his associates on the Chicago Ventilation Commission. It follows as a necessary corollary from the first principle of cool air-supply. Almost all school-ventilation systems, many systems in factories and some even in auditoria are constructed on the opposite principle, with inlets at the top and outlets at the bottom. Usually the outlets are placed just below the inlets on the assumption that the warm air as it enters will pass across the room, gradually become cooled and falling return along the floor. It is clear that the instant the room temperature rises above that of the incoming air, the system ceases to operate efficiently. As the cooler air enters it will tend to drop and pass to the outlet without affecting materially the general air of the room. These things are almost too obvious to dwell upon, but they must be emphasized as long as people continue to wonder why school rooms become overheated when supplied with warm air from ceiling inlets, an arrangement designed to frustrate every possibility of rational air conditioning. If the incoming air is to heat the room, and is to be cooled in passing through it, it is, of course, reasonable to introduce it from above. If it is of the same temperature as the room and driven solely by mechanical power, its point of entry is a matter which may be arranged as one pleases, according to local conditions. If, however, my first assumption is justified, if in order to guard against overheating it is essential that the incoming air should be below the temperature maintained in the room and should be cooled in its passage through it, upward ventilation is the only rational method.

(3) *Incoming cool air should be tempered,* unless the number of occupants in a room is small. The first two principles which have been stated do not necessarily presuppose "artificial" ventilation. We put them in practice, whenever we open our bedroom windows top and bottom. The question whether outside air should be tempered or not, however, launches us at once into the controversy as to artificial vs. window ventilation.

In considering the practicability of ventilation with untempered air it must first be decided what general temperature is finally to be maintained within the room. The advocates of natural window ventilation sometimes have in mind the maintenance of an ordinary room temperature of 65° to 70° by the admission of a small amount of cold outside air and sometimes advocate a frank abandonment of high temperatures in favor of open-air rooms which approximate more or less closely the conditions which may happen to obtain outside. The second condition involves a problem for the hygienist and student of human efficiency rather than the sanitarian. There is obviously no mechanical difficulty in leaving windows wide open—in "unhousing," to use Dr. Evans' picturesque phrase. Open-air treatment has, of course, been used with success in hospitals and sanatoria and in open-air schools. It is advocated by physicians of high standing for all hospitals and for all schools, but not, so far as I am aware, for auditoria and factories. Basing my judgment on my own predilections and on the broad historical fact that mankind has always manifested an instinctive desire to keep warm in winter I am somewhat doubtful whether indoor temperatures below 60° will ever become widely popular among normal human beings, except during sleep. If they do, the ventilation problem will be greatly simplified.

If, on the other hand, a temperature of over 65° is to be maintained, the cool air admitted for ventilation must be tempered in any rooms which are at all crowded. With only two or three people in a room, as in an ordinary dwelling, window ventilation can be successfully operated with pretty constant care. In a school or a factory, however, where there is a row of five or ten people extending from a window to the other side of a room, it is clearly impossible to ventilate by admitting untempered air in winter. Either the temperature near the windows will fall below 60° or the temperature at the other side of the room will rise above 70°—usually the latter.

I have been speaking so far of the maintenance of ordinary normal atmospheric conditions. The possibility of occasional temporary variations from this normal is another question. It is probable that sudden changes in temperature are stimulating and beneficial and a wind blowing over the body and dispersing the cloud of hot moist air which clings about it is certainly wholesome. Perflation, or the periodical flushing out of a room with drafts of cold air, is a good procedure whatever normal conditions may be maintained. It has been suggested that by opening windows in this way often enough, say once an hour, the necessity for artificial ventilation might be avoided. This would mean considerable interruption, however, to any continuous work and, like ordinary window ventilation, would lead to sharp fluctuations, the temperature being either very low just after windows were closed or very high just before they were opened. I am inclined to think that perflation is most useful as a supplement to a system of ventilation rather than as a system of ventilation in itself.

We must recognize that ventilation practice may differ very materially in different sorts of occupied rooms. In hospitals the conditions for natural ventilation are most favorable. The patients are compelled to accept what is thought to be good for them. They have no work to be interfered with and can be provided with all necessary clothing and covering to withstand low temperatures. They are not crowded. There are plenty of intelligent attendants to regulate window openings. Here, if anywhere, open-air treatment and window ventilation should succeed. In auditoria and offices and factories, on the other hand, the inclinations of the occupants must be considered, and in the latter the exigencies of more or less delicate manual work as well. Such rooms must be crowded and can rarely

count on constant skilled supervision. Here air tempering is, I think, quite essential. Schools occupy a somewhat intermediate position. Only experimentation can, perhaps, show clearly whether children keep permanently well and do good school work when exposed to the changing conditions of a northern climate accompanied, perhaps, by the dust and noise of a city street. The experience of open-air schools seems to indicate that subnormal children, with the special conditions of supervision, feeding, and medical care which have surrounded such experiments, are markedly benefited by the change, and further experiments along this line will be awaited with keen interest.

I have purposely said nothing about the mechanical method of supplying tempered air where tempered air is needed. It may be driven by fans from a central heating plant and may or may not be supplemented by exhausts. Or on the other hand, it may be supplied from exterior openings in the room provided with vento coils. Wherever air tempered to 60° is supplied, however, fans will probably be necessary to insure circulation in any crowded room, as temperature differences will generally prove inadequate.

(4) *Cool but tempered air must be evenly distributed within the space to be ventilated.* In regard to air distribution, both natural and artificial ventilation have in the past too often been failures. In the one case, however, the difficulty is inherent and in the other it is due to avoidable constructional defects. Barring the extreme case of the open-air school, where no temperature difference is maintained, it is obviously impossible to insure good distribution by window ventilation in cold weather in a room occupied by many people. The windows must necessarily be at the sides of the room, often at one side only, and there must be marked inequalities between conditions at the sides and at the center. On the other hand, there is no serious difficulty in securing almost perfect distribution by mechanical means, as is evidenced in many auditoria. Faulty construction is, however, far too common. This is a problem for the designing engineer and he must be in each case a true designing engineer, not the peddler of some quack "system" of ventilation. I cannot forbear to call attention to some of the common defects which are often forced upon the attention of the sanitarian. They appear principally at four points, in the construction of ducts and in the size, in the location and in the number of room inlets and outlets.

Main and branch ducts are frequently found to be constructed in defiance of every known law of air flow. They are too small or too large, they branch at improper angles, they coil round obstructions like unwieldly serpents. Often, someone else than the ventilating engineer is to blame for the last condition, but if he respects his work he should refuse to be party to its frustration. The careful experiments recorded in the "Second Report of the British Departmental Committee on Ventilation of Factories and Workshops," showed five years ago that the old practice of tapering main ducts to control air flow is a wholly mistaken one. They showed the vital importance of slanting branch ducts at an angle of 30°, yet these principles are still violated in many systems installed in this country. The sizes of inlets and outlets for individual rooms are often woefully inadequate. In my own institution a lecture room containing about 20,000 cu.ft. and seating 200 students, has four inlets with a total gross area of less than 10 sq.ft. Allowing a net area of 75% and a velocity of 3 ft. per sec., this gives only 750 cu.ft. per occupant. The temperature at the end of a lecture is sometimes 80°. The faulty location of inlets and outlets which is so common is mainly due to the old plan of downward ventilation which makes ventilation for cooling an impossibility.

Most important of all, in my judgment, is the question of the number of inlets and outlets. I do not know just how many cubic feet of a room should require a separate inlet, but I am quite certain that it is impossible to maintain good air conditions for fifty people with one or two fresh-air inlets. Short-circuits and air-pockets occur and marked local differences of temperature exist in rooms ventilated on the ordinary schoolroom pattern. In contrast to this condition is the marked success attained in many auditoria by the supply of air under every seat and in many factories where inlets and outlets are freely distributed about the room. Just how far to go must be determined by studying the conditions of each individual case, but I think it is clear that multiple inlets and outlets must be used far more freely than is now generally the case.

In all this I am, of course, suggesting nothing new. All these principles are carried out by the leaders in the ventilating profession, but so much rule-of-thumb work is turned out by architects and so called engineers of a different order that these facts must be emphasized to protect the whole art of ventilation from discredit.

The fundamental principles of the new art of ventilation, as I see them, consist, then, in the supply of a proper amount of air, cooler than the air of the room but tempered to a temperature above 60°, by multiple openings, sufficiently numerous to give good distribution and situated near the floor, with corresponding openings above for the removal of heated air. This is essential and this is all that is essential for the maintenance of proper temperature conditions and the prompt removal of odors and products of ordinary combustion and illumination.

There are other special problems of air conditioning which, though less important, are worthy of attention and are easily solved by minor additions to such a system as has been indicated. The first of these special problems is that of humidity. We have, so far as I am aware, no definite physiological knowledge as to the exact effect of dry air upon comfort and health. Very dry climates are often particularly healthful but, on the other hand, the warm dry air of our houses and schools seems to exert a distinctly unfavorable effect on many individuals. They find the dry atmosphere over stimulating and conducive to nervousness. It is said that the mucous membranes are clogged by too rapid evaporation and that diseases of the nose and throat result. We greatly need scientific study of these points. Meanwhile, however, there seems to be a sufficiently strong consensus of popular opinion to warrant provision for humidification, at least in hospitals and schools. At the Horace Mann School, in New York, very careful observations of the sensations of the occupants have led to the adoption of a mean temperature of 66° and a relative humidity between 55 and 60%, with general success so far as comfort is concerned. Artificial humidification may now be provided by any one of several methods with reasonable certainty and at reasonable expense.

Another point which is worthy of attention in certain cases is the washing or filtering of the incoming air to free it from its burden of dust. In libraries, telephone exchanges, dairies and other buildings used for special purposes this may be essential. In hospitals and schools it may be desirable under certain conditions. In a recent study of the air of certain New York schools, Prof. Baskerville and I found averages ranging from 610,000 to 760,000 dust particles per cubic foot in the air of five different schools with maxima running up to nearly 2,000,000 particles per cubic foot. This was in spring with window ventilation only. I know of nothing that would lead me to believe that these particles in such amounts are injurious to health. If, however, their removal is desired it can easily be accomplished.

One point which I do believe deserves much more attention than it has generally received is the possibility of air conditioning in warm weather. It is somewhat strange that we freely pour out money to heat and even overheat our buildings in winter and seldom think of cooling them in summer. Yet one procedure is quite as practical as the other and perhaps more important from the standpoint of public health. At the banking house of Kuhn, Loeb & Co., in New York, A. M. Feldman has designed the heating system so that it may be used for cooling in summer. A temperature about 10° below that of the outside air

is constantly maintained and I am told that the firm finds just one serious trouble with the plant, that people who come into the office in hot weather can never be persuaded to leave it. The Mt. Sinai Hospital, in New York, has planned a special cool room for young children, and in view of the direct relation between heat and infant mortality there can be no doubt of the value of such a provision. Two of the new hotels in Chicago are equipped with cooling plants. If we should cease to accept summer heat in buildings as a dispensation of Providence and balance in each case the cost of artificial cooling against the advantage to be gained, this procedure might be used to an extent now undreamed of.

The problem of operation will always remain to be considered. No amount of skill in designing will ever produce a ventilating system that is fool-proof. Notably successful results can only be achieved by constant supervision. Thus at the Horace Mann School, in New York, excellent conditions are maintained by the keen interest of the Superintendent of Buildings and Grounds, in spite of certain features of construction which seem to me unfortunate. Huntington Hall, at the Massachusetts Institute of Technology, is famous for its "good air"; and the reason is that Prof. W. T. Sedgwick takes personal charge of the temperature arrangements and watches the thermometers in the hall during the Lowell lectures which are held there. Such supervision as this is, of course, neither generally practicable nor generally necessary. An engineer or janitor intelligent enough to read a thermometer and conscientious enough to obey orders is all that is necessary, but the political derelicts who sometimes drift into school janitorships do not always meet even these simple tests. Even with good janitorial assistance, however, it would be highly advisable for every new plant to be operated for a short time under the supervision of its designer with careful studies of results as regards temperature and humidity and circulation. After such tests clear and simple rules for operation could be formulated which would give reasonable assurance of success; and they would prove of inestimable educational value to the engineer himself.

## A Consideration of the Unknown Factors in the Ill Effects of Bad Ventilation*

By Dr. Yandell Henderson†

The facts regarding ventilation present an extraordinary contradiction. Fresh air, sunlight and dry cool climates exert a decidedly beneficial effect upon health. Ill-ventilated dwellings decrease vitality. In some persons under certain conditions even a few minutes in a crowded room may produce acute ill-effects. As to how these effects are produced physiology has up to the present time afforded no satisfactory explanation. The evidence is almost entirely negative. The ill-effects of bad ventilation can not be due to lack of oxygen. It is probable that they are not due to any considerable degree to excess of $CO_2$. The idea that they are due to some poisonous substance contained in the expired air has in recent years been regarded as untenable. Recently this conception has been revived in a novel form by the brilliant work of Rosenau. Even Rosenau's investigations do not appear, however, to afford the solution of this problem. The recent investigations of Hill in England and of Flügge and his pupils in Germany makes it highly probable that the effects of fresh or vitiated air are brought about not by a direct action upon the lungs, but indirectly through the skin. It appears probable that the temperature and moisture of the air surrounding the body are the essential elements.

According to the explanation to be suggested in this paper the condition of the skin exerts a potent influence upon the lungs. This may be in part a vasomotor reflex acting upon the pulmonary circulation. More probably it is a chemical or harmone influence upon certain pulmonary processes. The evidence accumulated during recent years indicates that the lungs are not mere passive organs through which gases diffuse as through non-living membranes. The investigations of Bohr, of Haldane and his co-workers and of the recent Pike's Peak expedition all tend to indicate that the lungs are the seat of vital activities of great importance to health. Thus under certain conditions the lungs secrete oxygen into the blood, and it appears that considerable oxidation may take place in the blood during its passage through the pulmonary vessels. The evidence available, although still far from complete, suggests that these pulmonary activities are indirectly but powerfully influenced through conditions affecting the skin, and that it is in this manner that ventilation influences health.

*Official abstract.
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## The Effects of Temperature and Humidity on Fatigue*

By Prof. Frederic S. Lee†

With human beings the relation between temperature, humidity, and fatigue is shown most clearly in life in the tropics and in those industrial occupations, such as mining, baking, laundering, and some varieties of cotton weaving, in which the individual is obliged to labor in a hot atmosphere containing much moisture. Not only are sensations of fatigue then common, but the power of performing work is distinctly lessened and actual fatigue comes on earlier. The explanation of this condition is to be found in the peculiar physical and chemical changes that occur within the body laboring under the unusual environmental conditions. The high external humidity lessens the evaporation of sweat and the accompanying elimination of bodily heat; the temperature of the body therefore rises above the normal, and a febrile condition results. This febrile condition affords the proper chemical conditions for a pronounced susceptibility to fatigue. It has been shown that in fevers, whether of bacterial or other origin, there is increased catabolism, especially of the proteins of the tissues.

This phenomenon is not unlike that found in exhaustive muscular work. The cleavage products of the protein molecules are probably incompletely oxidized, and intermediate metabolic products accumulate in the blood. The store of such products of metabolism is much increased if at the same time muscular labor is performed. It has been shown that intermediate metabolic products, such as lactic and other acids, are toxic or fatiguing to muscles.

Furthermore it is known that poisons act on living cells more powerfully at higher than at lower temperatures. In a body, therefore, laboring in an atmosphere of an elevated temperature and charged with much moisture, we find exactly the conditions that are needed for the early oncoming of fatigue—a store of toxic fatigue substances and tissues possessing an unusually great susceptibility to the action of such substances.

*Official abstract.
†Columbia University College of Physicians and Surgeons, New York City.

**All-Steel Passenger Cars** are gradually replacing the old-style wooden coaches on all the Pennsylvania R.R. lines. Since June, 1906, all additions to the passenger equipment have been cars of all-steel construction. These cars weigh 118,500 lb., compared with 85,000 lb., the weight of a standard vestibule wooden coach. But 125 lb. of wood are used in the construction of each car, for window frames and arm rests of seats. The cars are constructed with a central box girder, 24 in. wide by 19 in. deep, extending the whole length of the car, which makes it practically impossible to have a car telescoped in a collision. There are at present in service on the Pennsylvania R.R. lines 1538 coaches and combination passenger and baggage cars, 68 dining cars, 144 baggage, 159 postal, 34 baggage and mail, 11 Long Island R.R. parlor cars, 4 miscellaneous cars, and 520 Pullman cars. In addition to these there are ordered or under construction at the present time, 296 coaches, 18 dining cars, 25 passenger and baggage cars, 2 baggage, 4 postal, 38 baggage and mail, 10 Long Island R.R. parlor cars, and one office car.

# The Cylindrical Valves for the Panama Canal Locks*

Each lock chamber of the Panama Canal locks is equipped with ten specially designed cylindrical valves, which control the flow of water from the culvert within the center wall to the well openings in the floor of the lock. Separate valves for each lateral opening from the center culvert are necessary in order that the twin chambers on opposite sides of the culvert may be used independently. The flow of water from the culverts in the side-walls is controlled by Stoney gate-valves opposite the ends of each chamber. In all there are 120 cylindrical valves.

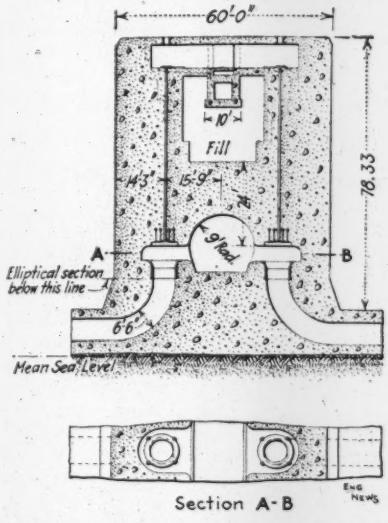



FIG. 1. CROSS-SECTION OF CENTER WALL OF LOCKS, SHOWING CULVERT AND LOCATION OF CYLINDRICAL VALVES

The accompanying illustration, Fig. 1, shows the position of the valves and the operating machinery with respect to the center-wall culvert. The valves are embedded in the concrete, in a chamber approximately rectangular in shape, 4½x13 ft., during the construction of the wall. Each valve consists of two concentric hollow cylinders, the lower one sliding within the upper. The opening is closed when the movable lower cylinder is in its lowest position, as shown in Fig. 2. The lower end of the movable cylinder then rests on a turned metal surface or valve seat, shown in detail in Fig. 3. At the sliding connection with the outer cylinder a watertight joint is made by means of leather washers, shown in Fig. 4.

The seal consists of two washers made up in sections of leather ¼ in. thick and held in place by segmental plates bolted to the flanges of the cylinder. The leather projects ½ in. beyond the flange, and under normal conditions about ¼ in. of leather is in contact with the opposite flange. This distance may vary by $\frac{3}{32}$ in. either way, which is the radial clearance of the valve and casing.

A flexible seal is used at the top of the valve, because if a solid contact were used at both top and bottom it would be practically impossible to have both tight at the same time on account of mechanical irregularities, which are likely to exist in machined parts of this size. When a flexible seal is used, the gap will be closed, even though variations in the level of the seal exist.

An investigation of the valve equipped in this manner, however, disclosed the fact that although leather is classed as a flexible material it still possessed enough stiffness to hold the valve off its seat when sufficient difference in the level of the flanges existed. In order that the leather seal should allow the valve to take a proper seat under the conditions described, the edges of the segmental plates nearest the free end of the leather seal were beveled as shown in Fig. 4, thus allowing the leather to bend at an increased radius for any irregularity of the flanges.

Leakage tests made after this modification was completed showed a leakage under a 60-ft. head of 0.014 cu.ft. per sec., which was a vast improvement over the previous tests, which showed leakage in excess of 0.5 cu.ft. per sec. All valves of this type are accordingly being modified in the manner described.

In order to soften the leather seals as much as possible, they are being removed and treated with a mixture of neatsfoot oil and paraffin, prepared as follows: Two parts of neatsfoot oil and one part paraffin are boiled until the paraffin is absorbed by the oil. This solution is then cooled and the leather soaked for about 72 hr., after which period it is found to be soft and pliable and thoroughly saturated with the compound.

When the valve is entirely open the movable cylinder is raised, leaving a 2-ft. 1½-in. opening completely around the valve. The outside diameter of this cylinder is 7 ft. 1⅜ in., and the diameter of the opening beneath the valve is 6 ft. 6 in. A distance of 3 ft. below the valve opening the conduit is elliptical in cross-section with a major axis of 8 ft. and a minor axis of 6 ft. 6 in.

The stem for raising the valve cylinder is moved by a revolving screw actuated by a bevel gear, which is driven by a pinion on an extension of the motor shaft. A small oil pump geared to the motor shaft lubricates the thrust bearings and the motor shaft extension bearings.

When the valve reaches its seat, shock to the machinery is prevented by allowing the thrust screw to rise through the thrust sleeve, giving the motor time to stop without shock. The valve-operating motors are controlled from a central tower as described in ENGINEERING NEWS, Mar. 21, 1912, p. 527.

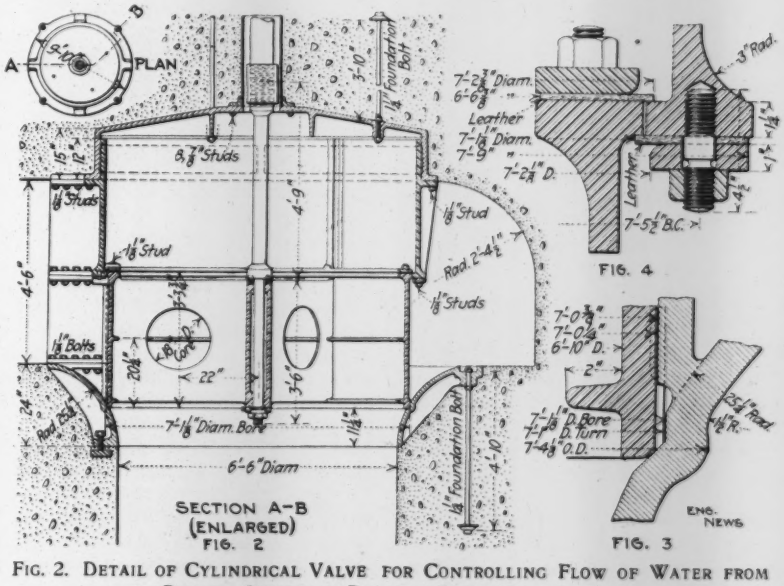



FIG. 2. DETAIL OF CYLINDRICAL VALVE FOR CONTROLLING FLOW OF WATER FROM CENTER CULVERTS, PANAMA CANAL LOCKS

FIG. 3. DETAIL OF VALVE SEAT

FIG. 4. DETAIL OF WATERTIGHT SEAL BETWEEN CYLINDERS

*From data in the "Canal Record" of Nov. 16, 1911, and Sept. 25, 1912.

**Dispatching of Trains by Telephone** over the entire main line of the Canadian Pacific Ry. from the Atlantic to the Pacific, a distance of 4000 miles, is now announced. It is expected that the arrangements will be completed and all apparatus installed for the complete system before the end of 1912.

# Grinding Rails on Street Railways

**The grinding of rails in place in street railway track is a rather novel feature in track maintenance. It is also a troublesome and costly feature, but has been made necessary in many cities by the development of transverse corrugations on the rail heads. The extent of the difficulty has led to the design of special machines to do the grinding, and the article given below describes the conditions of the problem as they exist in Chicago, and the methods employed by the railway companies for restoring a smooth running surface to the heads of the rails.**

The two companies which operate almost the entire electric street-railway system of Chicago (approximately 700 miles) are having a great deal of trouble with that class of rail wear known as rail corrugation, in which a series of waves or corrugations develop along the head of the rail. In both cases the matter has been investigated, with rather indeterminate results, and a large amount of work has been done in the way of grinding the rails in the track to remove the corrugations and give a new smooth running surface for the wheels. One reason for the investigation was the belief that the cost of car-maintenance was being increased by the vibration of the cars due to the corrugated rails. Information as to the trouble and the means of remedy has been obtained through the courtesy of Harvey B. Fleming, Vice-President of the Chicago City Ry., and John Z. Murphy, Chief Engineer of the Chicago Railways Co. In our editorial columns we have commented upon some aspects of this problem.

On both of these roads the tracks are laid with 9-in. 129-lb. grooved girder rails. The former line has both steel and wood ties, largely on a concrete base, but partly on stone ballast; where the tracks are on old cable lines the concrete is about 36 in. deep, but in other places its depth is 6 in. The tracks giving trouble are in general three or four years old. The latter line has mainly wood ties, either on 6 in. of concrete or 8 in. of broken stone, and the tracks examined for corrugations were generally two or three years old.

### Chicago Railways Co.

In a statement prepared for us by J. S. Bowman, of the engineering department, it is stated that there is such a diversity of opinion as to the cause of corrugation of rails, that no definite conclusion can be arrived at, but it seems apparent that the corrugations develop only in rails embedded rigidly (as in a concrete base), and that they are developed by such irregularities as low or loose joints. There is no consistency or uniformity in the way in which the corrugations develop. On some lines they are practically continuous for several blocks, then for some distance they are entirely absent, and then for a space appear only in spots. Other lines have only a few spots or corrugations, and still others have none at all. The corrugations do not cause hard riding of the cars, but they cause a loud and disagreeable noise when a car passes over them, and this is very objectionable to people living along that part of the street. They cause also a decided vibration of the car truck and of the electrical wiring and connections under the car, which results in considerable wear and tear of the equipment.

The depth of the corrugations varies from a few thousandths of an inch to 0.035 in. This latter is the greatest depth measured, but the men in charge of the grinding machine say that the corrugations are sometimes as deep as $\frac{1}{8}$ in. Those measured were on Madison St., where they seem to be the worst of any place on the system. The average depth was found to be approximately $\frac{1}{100}$ in. The distance from crest to crest of the corrugations varies from 2 to 5 in., averaging about 3 in., the longer ones usually being deeper than the shorter ones. The corrugations appear to the eye as small shallow waves in the steel surface.

The grinding is continued back and forth over the rails until the corrugations are entirely ground off, except in small spots where they are so deep that to grind them entirely out would leave a low spot in the rail. In such places the grinding is continued until the bearing of the rails and emery wheels is continuous and approximately ¾ in. wide on the low spots. The amount of grinding is left entirely to the discretion of the men in charge of the machine. The cost of grinding a foot of track (two rails) varies very considerably, depending on the depth of the corrugations, but an average cost is about 7.13c. per ft. This includes wages, interest and depreciation on the machine, and energy consumption. The last item is a very small part of the cost, averaging approximately 0.13c. per ft. of track.

The company owns the grinding machine and does the work with its own employees, two men being on the machine. It is the intention of the track department to treat as much of the system as needs it. On some lines this means continuous grinding for several blocks, since the corrugations are almost continuous. In other places the corrugations occur in a space of only a few feet, in which cases the rails are ground only at these spots.

### Chicago City Ry.

The corrugations in the rails do not cause noise or vibration noticeable to passengers, but there is a loud noise in the street when a car passes; this can be heard at a considerable distance and is unpleasant for residents along the line. There is also considerable wear of the trucks, due to the vibration and jar in running over the corrugations. There is no uniformity in the location or extent of the trouble, which may be continuous for several blocks, or may occur in stretches ranging from 5 or 10 ft. to 60 ft., or in isolated patches 12 to 24 in. or up to 5 ft. in length. In some places the corrugations are short and sharp, while at other places (perhaps closely adjacent to the former) they may be longer and more wavy. The table shown below from a report made by J. R. Boswell, of the engineering department, shows some of the results of observations on different lines.

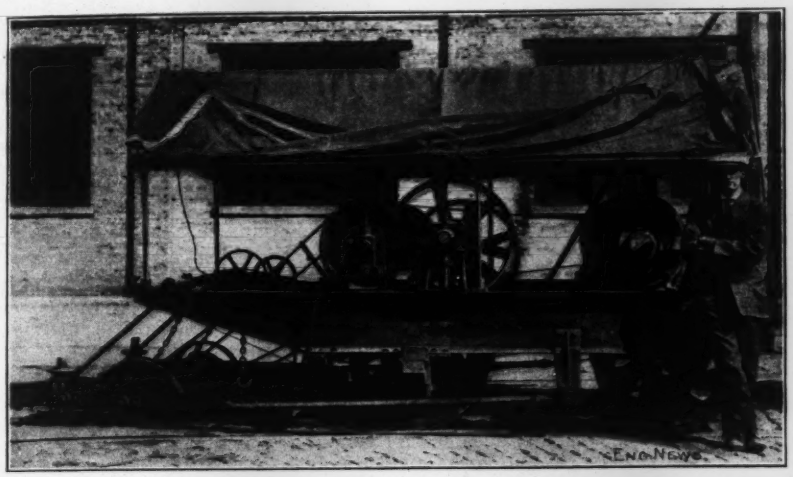
In grinding long stretches, the work is done over bad and good rail alike, giving a uniform finished surface. Very short stretches of corrugation, only 12 to 24 in. long, are ground to an approximate radius of 3000 ft., so that the depression below the level of the good rail at either end is not noticeable. Pockets at low joints are ground out also. The work is done on all parts of the system where this trouble develops. It is an interesting fact that corrugations sometimes reappear after the grinding. The explanation given for this is that the metal of the rail has been disturbed by the vibration to a depth below that of the new finished surface, and experiments are being made to determine to what depth the metal is thus affected.

TABLE OF RAIL CORRUGATION OBSERVATIONS: CHICAGO CITY RY.

| Street | Location | Percent of Distance Corrugated | Average Wave Length in. | Average Wave Depth in. |
|---|---|---|---|---|
| So. Chicago Ave. | 75th St. to 71st. St. | 21.10 | 3.19 | 0.0067 |
| Cottage Grove Ave. | 71st St. to 63rd. St. | 32.65 | 3.17 | ... |
| Cottage Grove Ave. | 63rd St. to 55th St. | 41.40 | 3.50 | 0.0100 |
| Cottage Grove Ave. | 55th St. to 39th St. | 65.25 | 3.68 | 0.0110 |
| Cottage Grove Ave. | 39th St. to 22nd St. | 22.90 | 3.45 | 0.0090 |
| Indiana Ave. | 22nd. St. to 18th St. | 46.10 | 3.75 | 0.0085 |
| 18th St. | Indiana to Wabash Ave. | 14.00 | 3.50 | 0.0070 |
| Wabash Ave. | 18th St. to Randolph St | 26.85 | 3.69 | 0.0080 |
| Indiana Ave. | 51st St. to 39th St. | 20.40 | 3.55 | 0.0060 |

Traffic was moderate on the first three lines and dense on the others. Speed was high on the third, fourth and fifth lines and moderate on the others.

This road is making experimental use of the Romopac compound rail,* and on this also the corrugation has appeared. The rail consists of a grooved-head channel bar, resting on a T-bulb which forms the web and base of the rail. The flanges of the channel are bent under the bulb-head by a machine traveling along the track, but in spite of the weight of the machine, the inward bending of the flanges tends to cause the head to curve slightly upward, so that it is not in close contact with the top of the bulb. This infinitesimal looseness of fit is sufficient to cause vibration and movement of the head which results in corrugation. A heavier machine, with a load of 23 tons on the rails, is to be tried in order to insure an absolutely close and tight fit of the two parts of the rail.




RAIL-GRINDING MACHINE FOR GRINDING OUT CORRUGATIONS WORN IN THE RAIL HEADS; CHICAGO CITY RAILWAY

The rail grinding is done by a machine owned by the company and operated by its own force. This is shown in the accompanying cut, and is described further on. The work is done only between 1 and 5 a.m., when the few "owl" cars can be run on single track past the section where the machine is at work. Portable surface crossovers have been purchased for use where traffic is heavier, to enable cars to be diverted to the other track. The work is slow, averaging 3500 to 4000 ft. per month. The cost depends largely on traffic conditions and the depth of the corrugations, but ranges on an average from 3.50 to 4.25c. per ft. of track. During May, 1912, two men with one machine ground 4030 ft. of track at a labor cost of 1.7c. per ft.

### OPINIONS AS TO RAIL CORRUGATION: CHICAGO CITY RY.

The principal causes of rail corrugation on this road are believed to be as follows: 1, a direct bearing on a rigid foundation; 2, long stretches of continuous rail with welded joints; and 3, irregularity of gage of track. As to the first two, the rails tend to buckle vertically and so work loose, while the traffic hammers them down upon the rigid base. In consequence, this road is not now using a concrete base on its new work. From Mr. Boswell's report we take the particulars given below, and in explanation of the types of track mentioned we may explain that these were developed by the Board of Supervising Engineers, which has supervision over all the street railways of Chicago and is composed of representatives of the companies and the city: No. 1, steel ties in concrete; No. 2, wood ties in concrete; No. 3, wood ties in a well compacted bed of stone ballast. These types were described and illustrated in our issue of Nov. 3, 1910. The following is from the report mentioned above:

Other conditions remaining the same, the amount of corrugation varies directly with the speed of the cars and the amount of traffic. Practically no corrugation occurs at street crossings, except in two cases where curves are located at the street crossing. Loose rail is usually found to be corrugated, and nearly all heavily corrugated rail is found to be loose. The type of track which is most rigid shows the heaviest corrugations.

Conditions favorable for rail corrugation are loose rail (held tight at joints not too far apart), concrete bed, continuous or welded joints, high speed and heavy traffic. The corrugation is caused by the cars, at a rather high rate of speed, passing over a suspended or loose section of rail. The car upon entering this loose section causes the rail to vibrate, and in passing over this vibrating rail it pounds on the rail at certain intervals, depending upon the frequency of the vibration. Since the bed is absolutely rigid (except in track of type No. 3), the rail cannot transmit this pounding to the roadbed, and hence will have to withstand all of the force thus exerted against it. As a result, we have this pounding ground into the tread of the rail.

There are two causes which tend to cause corrugation on curves such as those on Cottage Grove Ave. at Oakwood Blvd., and north of 29th St.: 1, the rail receiving the sliding motion of the wheels, and 2, the same vibrating action which causes corrugation on straight track. It is evident that if the wheels on the outside of the curve roll normally on the rail, the wheels on the inside rail must slip forward in relation to the roll of the outside wheel, and as a result of these two actions, the corrugation at curves where the speed is not reduced, is especially heavy.

Probably the loose rail is caused by the upper part of the rail becoming heated more than the lower part, which causes the rail to buckle up, and the upper part to spread more than the lower part. The rail being practically one continuous strip is unable to lengthen, and consequently buckles up at the joint, causing the fastenings to loosen themselves from the ties, eventually forming the corrugation.

Suggested means for preventing corrugation are: 1, to have a bed of greater flexibility than in track of types Nos. 1 and 2, and more like type No. 3 (or even more flexible); 2, to make the rail absolutely tight without concrete, and 3, to allow in some way for expansion in order to prevent loose-rail trouble.

Various theories which have been advanced for the cause of rail corrugation are as follows: 1, the steel is too soft for such extremely heavy cars; 2, flat wheels pound waves into the rail; 3, the expansion of the rail on its upper surface causes the steel in that part to wrinkle [but this fails to explain why it did not straighten out when the rail contracted]; 4, stopping the cars too quickly; 5, the gage is either too narrow or too wide; 6, one rail is higher than the other; 7, there is quicksand under Cottage Grove Ave., so that the roadbed is floating.

### THE RAIL-GRINDING MACHINES

The machines used on both of the Chicago lines were built by the Kerwin Machine Co., of Detroit, Mich., and are of the type developed by John Kerwin, Superintendent of Tracks of the Detroit United Ry. Co., for the purpose of facing low joints. In that work, the rail ends were raised to bring the low spot (cut out at the receiving end) up to grade, and the surface was then ground down to this level. The machine, which is shown in the accompanying cut, has a frame of 15-in. I-beams mounted on a pair of axles with 33-in. wheels, and carrying a post with trolley arm. A 15-hp. motor is belted to a countershaft which has friction wheels to drive a train of gearing which is connected to one of the axles, and the shaft has also a pair of grooved pulleys for the single-strand V-shaped belts which drive the emery wheels.* When grinding, the machine can travel continuously forward or can run to and fro, and the emery wheels are driven at uniform speed independent of the travel of the machine.

*Eng. News, Sept. 28, 1911, p. 386, and May 24, 1906.

*This V-shaped "Peerless" driving or power-transmission belt is built up of links of steel and rawhide. (Engineering News, July 29, 1909).

The two emery wheels are carried in an angle-iron frame hinged to the end of the machine so that it can be swung up out of the way when not in use. The frame is about 6 ft. long, and on each side it has an emery wheel and two shoes (15 in. long) which slide on the rails. These shoes are 5 ft. apart, with the emery wheel between them, and with this length of bearing on the rail the wheel must grind to a uniform plane and cannot grind low spots. Two men form the operating crew.

## A Comparison of Cars and Trains for Street Railway Service

In a number of cities having congested traffic conditions, the question of increasing the street railway carrying capacity by the operation of trains of two cars each instead of by single cars, has been under consideration. This subject was discussed in a report presented at the recent convention of electric railway associations in Chicago by a joint committee representing the American Electric Railway Engineering Association and the American Electric Railway Transportation and Traffic Association. The committee had been instructed to consider the matter in relation to congested city service and to interurban service, but its present report deals only with city service.

### Conditions of Operation

The three alternative methods of operation include single cars, multiple-unit trains, and trail-car trains, and two-motor and four-car motor equipment is to be considered. The committee first laid out a schedule and compiled the cost per year for single cars on the basis of a 100-car service, the cost being taken in the main from actual service records. These figures are shown in Class 1 of Table I. The committee then worked out comparative costs for seven other systems of operation (Classes 2 to 8). These several systems are outlined in the table.

Basis of Comparison—The important general assumption for the comparison of different methods of operating service (Table I) are given below, but the committee states that it does not take the position that train operation should be confined to the limits noted.

A. Schedule speed 8½ m.p.h. for rush hours, except trailer operation, which is taken at 4 and 5% less, due to less power per ton of train.

B. Rush-hour headway not exceeding two minutes for single car operation with 100 cars in operation during rush hours and 50 cars during midday..

C. Seating capacity of all cars, 60.

D. Car mileage and receipts per car mile the same in all cases.

E. Fixed charges, covering interest, depreciation, taxes and insurance, 12%.

F. Platform expenses, 25c. per hour per man.

G. Total cost of power at the car 1.25c. per kw.-hr.

H. Train operation covers two cars only, in train.

I. All cars of single, combined entrance and exit type for double end operation and equipped with improved devices for handling passengers and reducing accidents.

### Comparison of Results

It will be noted from Table I that where multiple-unit equipment is used and trains are operated during the rush hours, the cost of maintenance, fixed charges, platform expenses and power is slightly less than the single-car operation; and where multiple-unit equipment is used from 6 a.m. to 6 p.m., there is a decided advantage over the single car operation. The trailer operation, in the comparison of the four-motor equipments, is even cheaper than the multiple-unit operation and shows that where trailers can be used with all of the motor cars during the rush hours the extra cost of the larger motors is more than counterbalanced by the saving due to purchasing fewer motor cars and more trailers.

The conditions assumed as to cars, equipment, service, etc., are, to a certain extent, theoretical, and the conclusions are not applicable to all conditions, although they represent an average condition covering congested city operation, and for the types of equipment considered are comparative. Local conditions must dictate as to the method or combination to be used.

In addition to the direct financial results shown in Table I, the committee suggests the following indirect results due to the operation of cars in trains:

1. The loss of time due to extra or longer stops involved in train operation will be offset by the saving in reduction of traffic interferences and at car-crossing intersections, and the schedule speed will be as high in train service as in single-car service, where all cars are equipped with motors of the same size. This is a general statement based on analysis of service tests covering average conditions of traffic interference and schedules. If the interference from traffic is abnormally high, the schedule speed will be materially increased with train operation; and if abnormally low, it will be decreased, due to a greater number of, or longer, stops. Where delays from traffic are abnormally high, and also on lines or portions of lines where cars are of necessity operated at such close intervals that the efficient track capacity has been exceeded, two-car train operation will be of considerable benefit in increasing schedule speed.

2. The total accident cost will not be increased, and accidents due to collisions will be reduced. This statement is based upon the assumption that modern cars and appliances are used, where all entrances and exits are protected with doors and the boarding and alighting of passengers is only permitted when the train is stopped.

3. No advantage has been credited to the use of trains for emergency service, such as baseball games, park and picnic traffic, but it is evident that there are a number of occasions each year where train operation could be put into service to meet the emergency conditions in a more satisfactory manner and with increased revenue.

4. Where headways in single-car operation are now at a minimum, it is possible to install train service and carry additional passengers with an increased net financial result above that shown in the table. This is due to the fact that train service permits a greater number of cars to be operated over the same trackage.

TABLE I. COMPARISON OF ANNUAL COST OF OPERATION OF STREET RAILWAYS WITH SINGLE CARS AND TWO-CAR TRAINS (ON A BASIS OF 100 CARS PER YEAR)

| Class of Service | Car Equipment | Operating Service | Fixed charges | Platform expenses | Maintenance and inspection | Power | Total |
|---|---|---|---|---|---|---|---|
| | | | $ | $ | $ | $ | $ |
| 1 | Two 55 hp. motors; K control | Single cars all day | 58,968 | 192,237 | 60,400 | 108,716 | 420,421 |
| 2 | Two 55 hp. motors; four-motor controllers and coupler cables between cars, so that two two-motor cars can be operated as a train | Single cars; except two-car trains from 6 to 9 a.m. and 4 to 6 p.m. | 64,282 | 171,884 | 64,057 | 108,030 | 408,253 |
| 3 | Two 55 hp. motors; multiple-unit control | Single cars; except as in Class 2 | 64,800 | 171,884 | 64,430 | 108,135 | 409,249 |
| 4 | Two 55 hp. motors; multiple-unit control | Two-car trains; except single cars from 6 p.m. to 6 a.m. | 64,800 | 157,828 | 64,430 | 105,588 | 392,646 |
| 5 | Four 30 hp. motors; K control | Single cars all day | 68,299 | 192,237 | 66,902 | 127,189 | 454,627 |
| 6 | Four 30 hp. motors; multiple-unit control | Single cars; except as in Class 2 | 74,390 | 171,884 | 70,832 | 125,948 | 443,054 |
| 7 | Four 30 hp. motors; K control | Single cars; except from 6 to 9 a.m. and 4 to 6 p.m., when 53 motor cars operated singly and 26 motor cars with 26 trailers in two-car trains | 64,215 | 185,615 | 70,348 | 120,913 | 441,091 |
| 8 | Four 37 hp. motors; K control | Single cars; except from 6 to 9 a.m. and 4 to 6 p.m., when 52 motor cars and 52 trailers operated in two-car trains | 55,962 | 178,709 | 65,165 | 116,423 | 416,259 |

### General Conclusions

The selection of the type of equipment to be used depends upon local conditions. In the four-motor cases the cheaper train, involving the trailer, may not be applicable to all conditions, as the question of grades, character of terminals, minimum headways, density of traffic, etc., may make the operation of the same unsatisfactory. But there are many cities where trailer service could be used at least to a limited extent, with considerable saving over single-car operation. In cases of extreme density of traffic, the multiple-unit train is to be preferred over a motor car with trailer, as the interruption of one train may be more serious than under conditions where the traffic is not so dense. The more flexible multiple-unit train (either two- or four-motor) would warrant its installation in the more extreme congested conditions.

Train operation is much more practicable today than in the past, and in comparing single car and train operation this fact should receive prominent attention and train operation should not be condemned due to past faults either of equipment or operation. The single combined entrance-and-exit car particularly lends itself to this character of service, and if equipped with doors opened only when the car stops, throws a safeguard around the operation. The introduction of combination couplers, including the air hose, has simplified the problem of train operation. The coupler situation is not as satisfactory for city cars as is desirable, but with the improvements now under way train operation should be practical and successful in so far as couplers are concerned.

The air brake equipments of today are so designed as to meet the train service satisfactorily, and with the straight-air emergency combination, two-car trains are handled with safety. As to the use of multiple-unit control, the apparatus as now manufactured is practicable for city service and the committee hopes that the near future will bring forth further developments in the design of lighter weight and lower cost multiple-unit control equipments.

### Two-car Trains for Street Railways

In regard to the problem of congested city service the committee recommends that operating officials give the subject of two-car train operation serious study and attention, as it is believed that a distinct saving is to be made by train operation during certain periods of the day over portions of the system. This study should be made from the standpoint of modern equipment, as such equipment has brought about a condition which makes the operation of trains much more attractive than in the past, and by the operation of two-car trains in place of single cars, under congested conditions a vastly improved service may be given which can only be considered by the public as an endeavor on the part of the company to better the conditions of the service.

### Trail Cars and Multiple-Unit Trains on Elevated Railways

In the discussion on this report, H. A. Johnson (Metropolitan West-Side Elevated Ry.) described the train arrangements on the Chicago elevated railways, and we give an abstract of his statement, as published in the daily convention edition of the *Electric Railway Journal*. He presented a list of the equipment of these roads, as shown in Table II.

TABLE II. CAR EQUIPMENT OF THE CHICAGO ELEVATED RAILWAYS

| | Motor cars | Trail cars | Total |
|---|---|---|---|
| Metropolitan | 225 | 262 | 487 |
| Northwestern | 148 | 200 | 348 |
| South-Side | 370 | 30 | 400 |
| Ch. & Oak Pk. | 64 | 123 | 187 |
| Total | 807 | 615 | 1422 |

All cars are equipped with multiple-unit control apparatus, the motor cars having the complete equipments and the trailer cars having train-line cable and suitable connector receptacles. To eliminate some of the objections to trailers and to increase the flexibility of trains both in the yards and on the road, all the trailer cars on the South Side line and 40% of those on the Metropolitan line are equipped with motormen's cabs and controlling apparatus so that the train may be controlled from one of these cars just the same as from a motor car. Accordingly many of the trains have a "control coach" on the head end during the entire run, and many other trains operating into stub terminals have a "control coach" on the head end for one trip and a motor car the next trip. This arrangement has worked out to entire satisfaction. Some of the trailer cars on the Northwestern line are now being equipped with cabs and controlling apparatus.

The trains as operated on the four elevated railways vary from two to five cars per train, and the proportion of motor cars and trailers in a given size train varies considerably. On the South Side line, practically all cars are motor cars, as there are only 30 trailers out of 400 cars. This is an ideal condition from an operating standpoint, as every car is a self-contained unit, capable of taking care of itself. Considering that each car is equipped with the same capacity of motors in horsepower per ton of weight, the acceleration and speed of a five-car train will be equal to that of a two-car train.

The motor cars on the Metropolitan, Northwestern and Oak Park lines are equipped with motors of practically the same capacity, but the number of motor cars per train varies as shown in Table III. This table shows that the motor capacity in horsepower per ton of train in the three-car trains on the Metropolitan is 87½% greater than in the four-car Oak Park train with one motor car. With the equipments protected by a current-limiting device, the acceleration of the five-car Metropolitan and Northwestern trains and four-car Oak Park trains with one motor car is slower than the acceleration of the shorter trains which are operated during nonrushhours.

The cheaper train involving the trailer may not be applicable to all conditions, and the more flexible multiple-unit train would warrant its installation in the more extreme congested conditions. A study of the operating conditions on the elevated railways of Chicago discloses a heavy but short rush-hour period morning and evening which demands approximately four times the amount of equipment used during the middle of the day. Under these conditions the heavy investment and higher maintenance cost for all motor cars is not justifiable.

On the other hand, with the locomotive system and trains varying from two to five cars in length, the movement of trains is considerably slowed up during the rush hours at the very time it is desirable to get them over the road as quickly as possible. After careful study it is believed that a combination of approximately equal numbers of motor cars and trailer cars equipped with cabs and controlling apparatus is the most economical and satisfactory.

TABLE III. COMPOSITION OF TRAINS ON THE CHICAGO ELEVATED RAILWAYS

| No. of Cars in Train | Metropolitan | | Northwestern | | Chi. & Oak Park | |
|---|---|---|---|---|---|---|
| | Train | Hp. per hr. | Train | Hp. per hr. | Train | Hp. per hr. |
| Two | 1 M., 1 T | 6.3 | 1 M., 1 T | 6.3 | 1 M., 1 T | 6.3 |
| Three | 2 M., 1 T | 7.5 | 1 M., 2 T | 4.5 | 1 M., 2 T | 4.5 |
| Three | .... | ... | 2 M., 1 T | 7.5 | .... | ... |
| Four | 2 M., 2 T | 6.3 | 2 M., 2 T | 6.3 | 1 M., 3 T | 4.0 |
| Four | .... | ... | .... | ... | 2 M., 2 T | 6.7 |
| Five | 2 M., 3 T | 5.4 | 2 M., 3 T | 5.4 | .... | ... |

**A Thermoelectric Bomb Calorimeter** has been brought out by Professor Fery, of France, according to a recent note in "Engineering." The calorimeter is very much simpler and quicker in its manipulation than the ordinary water calorimeter. The bomb is very small and is inclosed in an outer shell. The bomb itself is made the hot junction of a thermo-electric element, while the outer shell takes the place of the cold junction. The fuel being placed in the bomb and oxygen fed in under a definite pressure, upon ignition the combustion of the fuel causes an electric potential (read by a voltmeter) which corresponds accurately to the rise of temperature produced, which in turn is proportional to the heating value and may be read off a suitable graduation, provided the weight of fuel placed in the bomb is a fixed standard amount. Tests showed good results of the new instrument.

# Thermal Effects on Brick Pavements*

By James E. Howard†

**Brick pavements laid with cement joints have proved highly successful in recent years, and cement jointing is now accepted as essential to good construction. What becomes of the expansion and contraction in such "monolithic" pavements? Mr. Howard started some strain-gage tests on this question two or three years ago. His results and conclusions up to now are summarized below.**

*A paper read before the American Society of Municipal Improvements, at Dallas, Tex., Nov. 14, 1912; slightly condensed.

†Engineer-Physicist, Bureau of Standards, Washington, D. C.

An ideal street pavement is one which presents a smooth surface of such hardness and rigidity that the tractive effort of moving vehicles is reduced to a minimum; having a surface smooth, without slipperiness; of adequate frictional properties for the safe footing of men and animals and against the skidding of motor-driven vehicles; durable against abrasive wear, and of sufficient compression strength or sustaining power against concentrated wheel and toe-calk loads; one in which the physical properties are not materially modified by the usual range of atmospheric temperatures and which is practically nonabsorbent and impervious to moisture. These conditions are generally met in a pavement of vitrified brick of monolithic construction, the continuity of which is attained by means of cement-filled joints. If not confronted with destructive tendencies incident to changes in dimensions caused by changes in temperature there is apparently no reason why a well constructed brick pavement should not maintain a state of integrity and successfully endure traffic conditions for many decades of years.

An inquiry into the effects of changes in temperature on cement-filled brick pavements is an inquiry of a refined order, taking up the subject at an advanced stage, from a constructional point of view, but nevertheless involving questions of vital importance, the solution or adjustment of which will promote the success of this type of pavement and contribute toward securing that permanency which is desired.

### Physical Properties of Paving Brick

The crushing strength of vitrified paving brick commonly ranges from 10,000 to 15,000 lb. per sq.in., not infrequently reaching and exceeding 20,000 lb. per sq.in. The compressive modulus of elasticity is found to range ordinarily from 2,500,000 to 8,000,000 lb. per sq.in., with a value as high as 10,000,000 lb. per sq.in. occasionally observed. (In building bricks values below the above mentioned minimum are often displayed.) The compressive strength and modulus of elasticity increase as the weight per cubic foot of the bricks increase, while the porosity or rate of absorption of moisture decreases. That is, the more material there is in a given space the stronger and more rigid it is, and necessarily less porous. These are features which should be considered in a paving brick and they are features which are controllable in the process of manufacture; at least the apparent modulus of elasticity is modified by the conditions of burning the brick, while the crushing strength and density certainly can be controlled within limits.

As regards the value of the coefficient of expansion of brick, data are not as complete as desired. The values frequently seem to be in the vicinity of 0.0000040 per degree F., with some examples, however, approaching the values for steels, or above 0.0000060. A value of 0.0000040 has been accepted for the time being in considering some of the phenomena attached to the expansion of pavements, since this corresponds well with the observations which have been made on the behavior of the pavements.

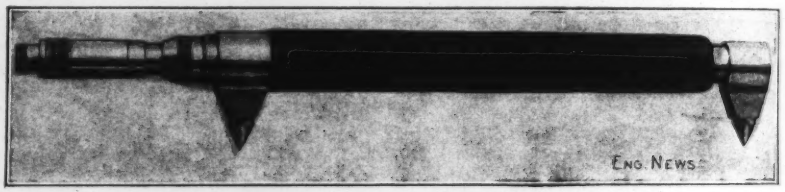



FIG. 1. MICROMETER STRAIN-GAGE

### Expansion Stress

In regard to the relation between modulus of elasticity and coefficient of expansion in respect to the force which the confined material would develop when raised through a range of temperature of 100° F., taking for examples four mud bricks selected from different parts of a downdraft kiln, the following Table I is presented:

TABLE I.—PROPERTIES AND EXPANSIVE FORCE OF FOUR MUD BRICKS

| Location in kiln | Modulus of elasticity, lb. per sq.in. | Crushing Strength, lb. per sq.in. | Weight per cu.ft., lb. | Confined stress for 100° F. Rise, lb. per sq.in. |
|---|---|---|---|---|
| Top | 10,000,000 | 19,170 | 144.3 | 4,000 |
| ¼ down | 7,692,000 | 15,670 | 136.4 | 3,076 |
| ¼ down | 5,263,000 | 10,420 | 130.6 | 2,105 |
| Bottom | 4,545,000 | 10,870 | 125.4 | 1,818 |

That is, bricks of these moduli of elasticity would be expected to develop, when confined and strictly prevented from expanding, compressive stresses ranging from 1818 to 4000 lb. per sq.in.

The bearing which these figures have upon the behavior of cement-filled brick pavements is this: The pavements will develop certain compression stresses when the temperature is raised, which stresses will be greater with brick of high crushing strength with high modulus of elasticity in comparison with those of a lower modulus of elasticity. Only a portion of the possible maximum confined stress will be realized, but in any case the relative expansive force exerted should be proportional to the moduli of elasticity and, since the highest values pertain to the strongest brick, those pavements constructed of the strongest material will be capable of exerting the highest stresses which are incident to rise of temperature. It would, in some cases, relieve the magnitude and severity of thermal effects to restrict the brick to a grade sufficient to provide adequate abrasive resistance for traffic conditions of a particular street. The endurance of brick pavements against abrasive wear has been found from experience to be so great that no trouble is ordinarily apprehended in that direction.

The observed expansion of cement-filled pavements, in a direction crosswise of the roadway, has corresponded closely to a coefficient of expansion of 0.0000040 per degree F. In Table II, however, the computed expansion of roadways of different widths is given for a range of temperature of 100° F. for assumed coefficients both of 0.0000040 and 0.0000060. The table gives the total computed expansion, one-half of which might be taken as occurring at each side of the street.

Although the maximum stresses which the confined material could display would range in round numbers from 25,000 to 50,000 lb. per individual brick, yet the

TABLE II—COMPUTED EXPANSION OF CEMENT-FILLED BRICK PAVEMENTS FOR 100° F. RISE

| Width of roadway | Assumed coefficient of expansion 0.0000040 | 0.0000060 |
|---|---|---|
| 4 ft. 8 in. | 0.0224 in. | 0.0336 in. |
| 14 ft. | 0.0672 | 0.1008 |
| 25 ft. | 0.1200 | 0.1800 |
| 30 ft. | 0.1440 | 0.2160 |
| 40 ft. | 0.1920 | 0.2880 |
| 50 ft. | 0.2400 | 0.3600 |

street curbing could not ordinarily afford any such reaction. Curbing which is backed up by earth filling yields to moderate pressures when they are long sustained, and in a crosswise direction pavements would not be expected to develop forces of very great magnitude in the absence of substantial buttresses. The fact that the middle of a roadway rises during the period when the bricks reach a high summer temperature is occasioned and facilitated by the crowning of the roadway. The usual pavement is, in transverse section, a bent column of very slender proportions, which easily deflects, increasing the crowning of the arch; this action may result in the formation of longitudinal cracks.

### Measurements of Thermal Effects

Observations have been made on pavements in Cleveland, Ohio, and vicinity, covering a period of over a year. They embraced measurements of changes in length both lengthwise and crosswise the roadways. Reference lengths of 20 in. each were established and defined by means of small bronze plugs inserted in the pavement. The tops of the plugs were about ⅜ in. below the surface of the pavement, and were protected against traffic by paper washers and putty. These plugs had in their upper ends small drilled and conically reamed holes, from center to center of which measurements were made.

A strain-gage of the style shown by Fig. 1 was used for measuring purposes.* Generally the readings of the gages checked to one ten-thousandth inch, although that degree of accuracy will not be claimed for the work; it is believed, however, that changes in the reference lengths were measured reliable within two ten-thousandths inch. A steel reference bar is used in connection with the strain gage.

### Measurement of Load Effects

In addition to the measurements with the strain gage on changes in dimensions due to changes in temperatures, the work at Cleveland included a number of observations on the elastic depression of loaded pavements and the depression of trolley tracks under the weights of cars, by means of a leveling-beam. One end of the beam rested upon the track, the other end, 4 or 7 ft. away, upon the pavement; the beam is provided with a sensitive level and a micrometer elevating screw.

There is a general depression of the pavement and roadbed in the vicinity of a car, but slight in amount when compared with the depression of ordinary trolley track. Depression of trolley track usually takes place to such an extent as to make it undesirable to bond the pavement to the track. When a very sensitive level bubble was used the depression of the pavement could be detected some 10 ft. from a trolley car in the direction of the curbstone; this was found on a tar-filled pavement. At an intersection the approach of a man when 12 ft. distant was indicated by this sensitive level.

Monolithic brick pavements are very elastic. They depress locally under loads and spring back when released.

### Early Cracks in Brick Pavements

In conjunction with the measurements of changes in the 20-in. reference lengths there were observations on the incipient formation of transverse cracks in freshly grouted pavements. The first 24 to 48 hr. after grouting is a critical period in the laying of a cement-filled pavement. The grout during the first few hours after applying has very little strength and, like cement structures in general, it cannot safely be disturbed during the period of setting. A drop in temperature

Fig. 2. Transverse Crack in Brick Pavement Opposite Joint of Curbstones
(Andrews Ave., Lakewood, Ohio)

of the brickwork of 30° from day to night is not uncommon. An uncovered pavement can hardly endure this drop in temperature without starting incipient cracks. A thin layer of sand on the pavement aids somewhat against the joints being put into a state of tension by the lower temperature of the night. It is probably quite impracticable to use a sufficiently deep layer of sand to entirely protect the pavement against this drop in temperature, while the grout is acquiring strength.

Incipient cracks appear at first as fine dark lines, darkened apparently by the presence of moisture. Later the lines are white, caused probably by the line in the cement of the grout going into solution and then being converted into the carbonate. These phases have been observed, although they may not be conspicuous in all cases. It is safe to say that thermal cracks must be recognized as a probability and their presence expected, and that they may have their origin in point of time prior to the opening of the street to traffic.

Fig. 2 shows a transverse crack in a pavement opposite the end joint of the curbstones, photographed before the street was opened to traffic. This street did not have an expansion joint, hence there was at least considerable frictional resistance between the pavement and the curbstones. The diurnal expansion and contraction of the curbstones would affect the width of the joint between them. In the case illustrated the brick followed the movements of the curbstones and a transverse joint in the pavement was developed. While this street did not have expansion joints at the curb, it will not be understood that streets with expansion joints are exempt from transverse cracks due to early changes in temperature. Observations tend to prove that such cracks are of common occurrence.

### Growth of Early Cracks

There seems a progressive development in these early transverse cracks, which first appear as fine hairlines and eventually have a measurable width. The presence of a number of such transverse cracks (and commonly quite a number are formed) leads to a lengthening of the pavement as a whole. The pavement of Andrews Ave., Cleveland, in ten months' time had extended in one direction and crowded over the marginal curb at the crossing of the tracks of the N. Y. C. & St. L. R.R. about ⅝ in., and in the other direction had crowded the asphalt pavement of Clifton Boulevard, carrying with it and deflecting the trolley tracks.

Some of the transverse thermal cracks which were developed in the pavement of Farmington Road, East Cleveland, were spanned by reference lengths of 20 in. each, and the progress of development observed. This street was paved about the first of August, 1911. Measurements of reference lengths established on the pavement were taken at intervals during the following months of September, October and November. The measurements of one reference length spanning a transverse crack showed that its development took place as follows:

TABLE III.—GROWTH OF TRANSVERSE CRACK, FARMINGTON ROAD, EAST CLEVELAND

| Date 1911 | Measured Width, in. |
|---|---|
| Sept. 22 | 0.0 (Initial reading) |
| Sept. 30 | 0.0080 |
| Oct. 23 | 0.0170 |
| Nov. 9 | 0.0250 |
| Nov. 13 | 0.0377 |

The temperature of the brick on Sept. 22 was about 90° F., while on Nov. 13 it was 32° F. This is an example of a wide crack. A remeasurement on the following August showed the crack very much reduced in width, the temperature then being 82° F.

In the progressive development of a transverse crack there is a probability of its not closing entirely when the pavement subsequently reaches a maximum temperature. Fine particles of sand or abraded material from the surface of the

*See also Eng. News, Mar. 23, 1911, p. 352, for a description of this gage and an account of some applications to a new kind of strain mesurements of great precision.—Ed.

FIG. 3. DIAGONAL CRACK IN DRIVEWAY ENTRANCE DUE TO CREEP OF CEMENT-FILLED PAVEMENT TOWARD TAR-FILLED PAVEMENT
(Kennedy Ave., Cleveland, Ohio)

pavement are likely to get swept into the crack during the daily drop in temperature and prevent the closing of the crack when the pavement again reaches a higher temperature. This process will be repeated until the pavement reaches a state of considerable longitudinal compression.

The middle portion of the length of the street would then remain in a state of more or less initial compression over certain ranges in temperature, while the ends, if unresisted, would extend measurably in each direction longitudinally. The part of the street which is under initial compression longitudinally is for the time being in a firm conditon and capable of sustaning traffic satisfactorily.

If the cracks are numerous and near together, and not under sufficient longitudinal compression, the sections then act independently. When depressed by the load of a vehicle an abrasive action will take place between the cracks and tend to enlarge them.

The pavement is believed to be in a favorable condition when under initial longitudinal compression, and the same would be true of lateral compression if the pavement was flat or had very little crowning. Initial compression as such seems advantageous, or a certain amount is advantageous. This state of compression may be reached and maintained along the middle part of a straight roadway, but difficulties are encountered at open ends in providing an adequate marginal curb to resist the thrust.

### TAR-FILLED ADJOINING CEMENT-FILLED PAVEMENT

Kennedy Ave., Cleveland, has been paved a year and several months. It is in three sections, of which the upper and lower ones are cement-filled, while an intermediate section has a tar filler. The street has expansion joints at the curbs throughout its length. A noticeable feature in the cement-filled parts of the pavement of Kennedy Ave. is its creeping toward the low-resisting tar-filled section.

The lower cement-filled section is traveling upgrade toward the tar-filled section and carrying with it a part of the pavement of a driveway entrance leading off one side of the street. The upper cement-filled section is compressing the intermediate section in a down-grade direction. This compressive force is felt at the ends of the tar-filled section, but not at the middle of its length. Along the center line of the roadway the 20-in. reference lengths in the tar-filled section were shortened 0.1155 in. and 0.1968 in., respectively, for the upper and lower ends of the section, between the dates of Sept. 29, 1911, and Aug. 25, 1912.

The travel of the lower cement-filled section, in an upgrade direction as it chanced to be, carrying with it a portion

FIG. 4. ASPHALT UPHEAVED AND MANHOLE COVER TIPPED BY CREEP OF BRICK PAVEMENT
(West 74th St. and Franklin Ave., Cleveland, Ohio)

of the pavement of the driveway entrance is shown by Fig. 3. The portion of the driveway pavement above the zig-zag crack was carried along by the general movement of the surface of the roadway.

### CREEPING OF BRICK PAVEMENT

Fig. 4 shows the creeping of a brick pavement and its effect upon an abutting asphalt pavement. A ridge in the asphalt was raised and a gas-main cover tipped by the movement of the cement-filled brick pavement. The weaker asphalt pavement readily yields to the pressure exerted by the brick pavement, while the latter itself is more or less cracked in that vicinity as it would be at an open end.

The creeping of a strong brick pavement disturbs manhole frames and carries along with it catchbasin gratings, as shown by Fig. 5. This pavement (Belmore Road, East Cleveland) showed a movement at the place photographed about equal to the width of the brick. One end of Belmore Road abuts against Euclid Ave., on which there is a double-track trolley line. The pavement of Euclid Ave. offered little resistance against the creeping of this side street, which condition facilitated the shearing of the catchbasin grating.

These illustrations are selected as typical examples, and it will not be necessary to refer to other similar instances. Having in mind the forces generated and their manner of development, it is generally an easy matter to consistently account for the effects of thermal conditions witnessed in pavements, and (where unbalanced forces exist) to predict those movements in the pavement which are realized.

There are places in pavements where only slight changes in dimensions have occurred for a temperature range of 50° or more. There is a compensation in the relief of initial longitudinal compression which occurs during a drop in temperature, and this has nearly or quite compensated for the contraction incident to the lowering of the temperature. The result, observed at a section of Euclid Ave., near University Circle, Cleveland, was the maintenance of substantially a constant or fixed gage-length. Obviously, a section where no movement of the pavement occurs marks a place of great durability. Without the disturbing factor of changes

FIG. 5. CATCHBASIN GRATING SHEARED BY CREEP OF PAVEMENT
(Belmore Road near Euclid Ave., East Cleveland, Ohio)

of temperature the construction and maintenance intact of a monolithic pavement would be much simplified.

Measurements of transverse reference lengths are in general more regular and follow changes in temperature more consistently than the changes in the longitudinal reference lengths. It may be remarked in passing that no substantial difference appeared between pavements with and those without expansion joints at the curb, in respect to the display of lateral expansion and contraction. In a longitudinal direction, occasional cracks across the roadway cause some reference lengths (these spanning the cracks) to be longer when the temperature is lowered by reason of the adjacent sections contracting and opening the joints. In few places is there strictly normal behavior witnessed in the longitudinal reference lengths.

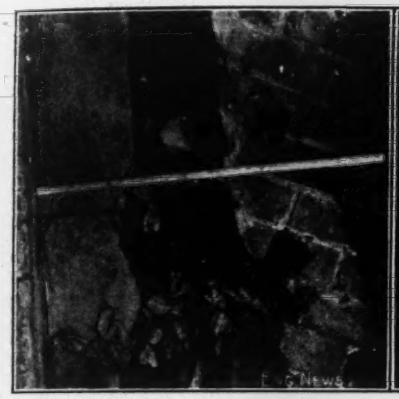


FIG. 6. INNER EDGE; 6-IN. GAP BETWEEN PAVEMENT AND CONCRETE GUTTER IS DUE IN PART TO CREEP OF PAVEMENT AND IN PART TO WEAR OF WHEELS

FIG. 7. OUTER EDGE, OPPOSITE POINT SHOWN BY LEFT-HAND VIEW; CONCRETE GUTTER FRACTURED BY OUTWARD THRUST OF PAVEMENT

INNER AND OUTER CURBS OF A CURVED STREET
(Carlyon Road near Superior Ave., East Cleveland, Ohio)

### EFFECTS AT CURVES

Figs. 6 and 7 show opposite sides of Carlyon Road, East Cleveland, at the curve in the roadway near Superior Ave. At the time it was photographed, this part of the street was being repaired. At the inside of the curve, as shown by Fig. 6, the pavement had left the cement gutter and was forced over against the opposite gutter, shown by Fig. 7. The open channel between the pavement and the cement gutter at the inside of the bend was 6 in. wide, a considerable part of which, however, represented the result of abrasive wear of vehicles; it was not all due to the bodily movement of the pavement. From 2 in. to 2½ in. represents the maximum movement which has been observed in other streets taking place in a direction away from the inside curb.

The pavement of Carlyon Road was under initial strains when the repairs were made. A portion of the pavement was torn up, whereupon the part shown in Fig. 6 gradually moved outward radially an additional distance of ¼ in., first observed, which was subsequently found to have increased to about ½ in. The pressure on the outer curb caused the fractures which are shown in Fig. 7. Sidewalk flagging afforded the necessary reaction to fracture the combined cement gutter and curbing.

In the case of Emily St., East Cleveland, which has a bend near one end of some 50°, the pavement has left the inside curbing for a distance of 160 ft., crowding over against the outer curb. Tension cracks are on the outside of the bent pavement and where the longer tangent of the street has acted upon the shorter one. At the inside curb the maximum opening between the pavement and the curb was found to be 2⅛ in.

The conditions in streets with short reverse curves are rather more severe than in single bends. The long tangents set up shearing stresses which fracture the pavement at the reverse curve. Fig. 8 shows such an example on Cummington Road, East Cleveland. The pavement was forced into close contact with the outside curbs of the bends, while at the inside curbs the openings were 1½ in. and 2 in., respectively. At the junction of Abington Road with Cummington Road, near the reverse curve of the photograph, there were two openings of 2½ in. each between the pavement and the curbstone. These several openings are believed to have been the result of the gradual lengthening of the pavements by alternate expansion and contraction. When cold, gritty material would sift into open cracks and prevent them closing subsequently when the pavement was next heated, this process being repeated, gradually causing a pronounced lengthening of the entire surface.

Some of the foregoing examples were taken from streets which have been paved for a term of years. The effects of changes in temperature are cumulative in part, and it would require several years to elapse before certain effects reach a maximum stage of development. Predictions based upon the relations existing between the coefficients of expansion, the moduli of elasticity, and the crushing strengths of the bricks lead to the inference that when thermal effects are considered the behavior of these earlier paved streets may be taken as examples of what should eventually be found in current construction.

Greater strength may reside in recently

FIG. 8. SHEARING FRACTURES AT REVERSE CURVES
(Cummington Road, East Cleveland, Ohio)

constructed pavements, but it may also follow that greater internal strains may be introduced by reason of the higher physical properties of the materials used. Internal generated forces depend for their magnitude upon the physical properties of the materials themselves. It is believed that thermal effects will be similarly displayed in pavements both of medium and of maximum strength.

tracks, in West 14th St., Cleveland, which are attributed to the transverse or crosswise bending of these paved strips. The expansion of such narrow strips as these would be only a few hundredths of an inch for a range of 100° F., and compression forces due to changes in temperature would not account for the formation of these cracks. These cracks appear to be due to crosswise bending

true, it is a mistaken idea to introduce transverse expansion joints in any part of a street.

### Expansion at Sidewalk Crossings

Fig. 12 illustrates an upheaval of a sidewalk crossing on Ravine Ave., Cleveland. It is quite unlikely that such a detail will again be used since the disrupting effect of exposure to high summer temperatures on such a feature is well known.

Longitudinal compressive forces are well resisted when the elements of the pavement parallel to its length are straight lines, but the introduction of sidewalk crossings sharply crowned, thus changing the elements to curved ones, makes very weak places, easily upheaved by rise of temperature.

Straight members, not curved ones, are employed in other engineering structures to sustain loads of compression and a street pavement is an engineering structure which is governed by the same laws

Fig. 9. Crack along Rail
(University Circle)

Fig. 10. Cracks between Rails and between Tracks
(West 14th St.)

Some additional illustrations are presented on features connected with the general subject of brick pavements.

### Longitudinal Cracks at Trolley Tracks

Fig. 9 shows a crack parallel to one of the rails of a trolley track at University Circle, Cleveland. Cracks of this kind are caused by the depression of the trolley track carrying down the pavement which is bonded to or in contact with it. Only track of the highest degree of rigidity can safely be bonded to. It is injudicious to bring cement-filled brick pavements against the rails of trolley track, generally speaking, and yet that may frequently be the most expedient course to adopt. It is not expected that all troubles will be eliminated even though the causes are well understood, and cracks must be looked for in certain places in monolithic pavements.

Fig. 10 shows some longitudinal cracks between the rails and between the

of the pavement, in reaching which result the depression of the tracks and possibly the yielding of the ties on which the track rests are important factors.

### Wood-block Expansion Joints

Fig. 11 shows the appearance of one of a number of single courses of creosoted wood blocks which were used in the pavements of East 32d St., Cleveland. These courses of wood blocks were introduced at intervals of about 150 ft., and were evidently intended for the purpose of performing the functions of a transverse expansion joint. The bricks adjacent to the creosoted wood blocks were spalled, in a number of places, as shown by the cut.

The middle of the length of a straight street is believed to need no expansion joint; as for the ends, they would be benefited by being confined by rigid marginal curbs rather than by the use of joints of a yielding character. This being as other structures which are similarly loaded. If there is a divergence in a pavement from the best form of compression member, that is a flat surface, for drainage, or other purposes, the departure should be a minimum.

Fig. 11. Spalled Courses of Brick along Expansion Joint of Creosoted Wood Blocks
(East 32d St., Cleveland, Ohio)

Fig. 12. Upheaval of Brick Pavement at Elevated Crossing
(Ravine Ave., Cleveland, Ohio)

### Conclusions

In conclusion, it is believed that:

1. The integrity of cement-filled brick

pavements can best be maintained by adopting such details of design and construction as will enable the pavements to resist forces of compression which are incident to alternate changes of temperature.

2. Provision to resist such compressive forces should apply to the pavement in both longitudinal and crosswise directions.

3. Initial compression, within limits, is a desirable feature to have in a pavement; it seldom happens that the maximum compressive stresses occasioned by rise of temperature are sufficient to cause injury to the bricks by approach to their crushing strength.

4. The middle parts of the lengths of straight streets are from position best located to maintain the continuity of the pavements intact.

5. Open ends of paved streets may be expected to display creeping tendencies.

6. End creeping is a consequence of a permanent lengthening of the pavement, and, while individual bricks of the pavement will successfully resist compression stresses incident to rise of temperature, still the total force thus generated is too great to admit of being entirely resisted by marginal curbs or other means available.

7. Streets having others enter from one side only are unfavorably situated in respect to being exposed to overstraining forces.

8. Curved roadways have a tendency to leave the inside curbing and crowd against the outside.

9. Continuous pavements will not be expected to remain intact at short reversed curves in roadways, at least in the case of streets having long tangent ends.

10. To successfully resist the compressive stresses caused by variations in temperature, pavements should be laid as nearly flat as feasible, i.e., with minimum permissible crowning.

11. Compression stresses in pavements in directions in which the elements are straight lines are advantageous rather than detrimental and assist in keeping the pavements intact. Conversely, compression stresses acting in directions in which the elements are curved are menacing to the integrity of the pavements. The compressive stresses referred to are those caused by thermal changes, which act in the plane of the pavement, and do not refer to loads or stresses normal to the surface of pavements, such as wheel pressures of loaded vehicles.

# Letters to the Editor

## The Highest Building Outside of New York

Sir—I note in ENGINEERING NEWS, Nov. 14, 1912, p. 914, that the L. C. Smith Building, Seattle, Wash., is called the "highest building outside of New York." I beg to take exception to this statement, as I am at present the engineer for the Union Central Life Insurance Co. Building, in Cincinnati, Ohio, which is actually the highest building outside of New York, being 509 ft. 2 in. from the street curb to the top of the tower, or nearly 40 ft. higher than the Smith Building.

GUNVALD AUS,
By Kort Berle.

11 E. 24th St., New York City,
Nov. 18, 1912.

[The Smith Building is 461 ft. from high curb to top of steel work (not 416 ft. as stated in the caption to Fig. 1 on p. 914). Although this is nearly 40 ft. lower than the Cincinnati structure, it has 42 stories as compared with 32 in the latter. This is probably the basis of the far Western claim of the "highest building outside of New York." Superlatives are apt to have "flare-backs."—ED.]

## An Opportunity for Cooperation in Engineering Exhibitions

Sir—I have read with interest the editorial in your issue of Nov. 14, p. 920, with regard to opportunities for coöperating in engineering exhibitions by having them "at the same place during different weeks throughout the summer and fall." This, if carried out, would doubtless soon develop a true science of *conventioneering* which, perhaps, many will say already exists.

It has been my experience to attend several conventions (principally in the interests of library workers) in which it was evident there was great room for improvement in helping one to employ the time spent at the convention much more efficiently.

Naturally, too, the flocking to one center would make hotel and railroad rates lower than at present. If such exhibits included technical books, then librarians, general and special, might be particularly glad to have their meeting in the "convention city" for a given year.

G. W. LEE,
Librarian.

Stone & Webster, 147 Milk St.,
Boston, Mass.
Nov. 16, 1912.

## Size of Boats, New York State Barge Canal

Sir—At the present time a commission of New York State officials and others is holding public hearings for the purpose of obtaining expressions of opinions regarding the size of boats to be used in transportation on the Barge Canal, as well as matters of operation.

The original size of boats proposed for the Barge Canal was 150 ft. long, 25 ft. beam and 10 ft. draft, having an approximate carrying capacity of 1000 tons; hence the name 1000-ton Barge Canal.

The original width of the locks was 28 ft.; this has been changed to 45 ft. The normal canal prism is 75 ft. bottom width. 123 ft. water width and 12 ft. depth, which gives an area of 1188 sq.ft. The cross-sectional area of the proposed boat is 250 sq.ft., which gives a ratio of 4.75. There are isolated sections of the canal, in the Clyde, Seneca and Mohawk Rivers, as also in Oneida Lake and elsewhere, where the channel width is 200 ft., more or less. On account of the width of the locks and these isolated sections it has been proposed by some that boats 40 ft. wide should be allowed to be used. With the same displacement (cross-sectional area) the draft would be 6¼ ft. It is feared by some that these wide boats would interfere seriously with traffic while navigating the normal channel, generally in passing. In order to maintain the ratio of 4.75, area of boat immersed to canal-prism area, the draft of 6¼ ft. cannot well be exceeded.

As the canal prism is the same on curves as on tangents (there being no widening) further complications would arise in the curved portions, which constitute a large part of the Barge Canal. Had the original width of the locks been preserved, the problem of proper size of boats would be easily solved, but with *wide* lock and *narrow* prism it is one of much speculation, and is a question that might interest some readers of ENGINEERING NEWS enough to present their opinions.

EMILE LOW.

606 Ashland Ave., Buffalo, N. Y.,
Nov. 16, 1912.

## Camp Sanitation

SIR—I read, with interest, the article in your issue of Oct. 17, on "Camp Sanitation," by R. C. Hardman. Not only is there an "advantage" to be derived from the enforcement of the principles laid down therein, but the question of public health is very seriously involved. Numerous typhoid and other epidemics can be traced directly to construction camps.

The reformer will have difficulty in bringing the contractor, and frequently the engineer, round to his way of thinking, for, up to the beginning of work on the Panama Canal, the subject was almost wholly ignored by engineers. Many engineers have little, if any, feeling of responsibility for either the safety or the health of the contractor's men, throwing this responsibility entirely on the contractor, who, in turn, will vigorously object to any interference with the care and management of his employees. He evades his responsibility for personal injury by having his men insured against accident.

Boiled down, it finally becomes a matter of discipline. The army gathered at San Antonio in 1911 was under much better discipline than the one gathered at Jacksonville in 1898. The camp at San Antonio was not only free from typhoid, but was also much more free from other so called camp diseases. The writer served in a volunteer regiment during the Spanish War and Philippine Insurrection. During a service of about a year and a half we had more men killed in action than died of sickness of any character. This is an unusual record; especially, as the casualties occurred in the 126 days of constant fighting and skirmishing immediately following the outbreak of February, 1899, while the losses from sickness extended over the entire 18 months. Marching, eating and sleeping, as we were, in the wet tropical regions north of Manila, where the numerous towns and villages were wholly lacking in sanitary conditions, our death list would have been larger had we not been serving under a thorough disciplinarian and a splendid soldier. The average American objects to being controlled to the extent that this implies. He forgets that in exposing himself to the results of bad sanitation he indirectly exposes others, which even in our "free and equal" country he has no right to do.

Maximum efficiency in any organization cannot be obtained without a condition of maximum health. Engineers and contractors, though they are willing to employ sanitary methods about their camps, will often meet either direct or indirect opposition from their employees. Men object to being told that they must keep clean, either personally or in their surroundings, at least up to a standard of cleanliness set by others than themselves. Rather than have trouble with his men, a contractor will ignore many things to which the sanitarian would object. Generally, he is not a disciplinarian where finances are not directly involved.

Greatly improved conditions are not obtainable without responsible authority, and I fear we will have to appeal once more to a paternalistic government. We have factory inspectors, building inspectors, food inspectors, and other inspectors galore; why should we not have camp inspectors under the direction of the State Board of Health, who can enforce rules similar to those laid down by Mr. Hardman?

WM. F. ALLISON,
Formerly Major, 1st S. Dak. Inf., U. S. V.
Lewis Building, Portland, Ore.,
Oct. 26, 1912.

## End vs. Side Construction for Hollow Tile Walls

Sir—There has recently been considerable discussion of the comparative merits of various kinds of hollow-tile walls. Among the papers bearing upon the subject the writer noticed one by Virgil G. Marani, in your issue of Oct. 3, 1912, p. 629, in which he makes several positive statements regarding the superiority of tile with vertical voids over those laid with voids horizontal. On the basis of these statements, which contradict conclusions reached by many other authorities, and also by Mr. Marani himself in a paper published in ENGINEERING NEWS, Feb. 8, 1912, p. 248, he proposes a set of specifications for the vertical type of construction. In the light of present uncertainty with regard to the matter, the use of such specifications seems manifestly unfair.

Mr. Marani attempts to show that the vertical type of wall construction possesses greater strength, both because the crushing stresses are applied along the "grain," and because a larger proportion of the clay itself is used to transmit stress, The first conclusion can at best be considered extremely doubtful; the second is invalidated by the fact that in laying ordinary tile with the cores vertical, joints must be broken to secure proper bonding, and thus those webs perpendicular to the wall secure no bearing.

As a matter of fact, the strength of a hollow-tile wall depends in any case not upon the shape of the tile, but upon the kind of mortar. As an example, consider a typical tile which is now widely used. This tile is a cube 12 in. on a side, with an outside shell ⅞ in. thick, and two sets of cross webs, each ⅝ in. thick, making nine holes through the block in one direction. The total net area of this tile is about 65.2 sq.in. on a section across the holes, and its permissible load in end construction according to Mr. Marani's specifications, allowing 400 lb. per sq.in., would be 26,080 lb. On the other hand its actual bearing area in end construction when placed in a wall would consist only of the shells and webs in line with the wall and would equal only 37.5 sq.in. The building laws of New York City (1906) allow 18 tons per sq.ft. on brickwork in portland cement mortar, which is equivalent to 250 lb. per sq.in. This gives an actual allowable carrying capacity of only 9375 lb. If the same tile were laid upon its side the actual amount of web area transmitting stress would remain the same, while the effective area of mortar bed might be taken as considerably greater. Of course, there might be considerations aside from strength which would prevent laying this tile horizontally, but there are several types of hollow tile blocks upon the market especially designed for such use.

THEODORE B. PARKER.
116 Nassau St., New York City, Nov. 12, 1912.

[The above letter was referred to Mr. Marani and he has replied as follows. —ED.]

Sir—With reference to the above letter, I would state that Mr. Parker is, in a sense, correct when referring to applying stresses along the grain. He states that "this conclusion can at best be considered extremely doubtful." It was because of the doubtful proposition referring to side construction vs. end construction that I witnessed exhaustive tests made on both types of construction, and as will be noted in my article of Oct. 3, 1912, the result of these actual physical tests is very much in favor of end construction.

While it is true that there are several tiles on the market that because of their peculiar construction or patented interlocking or other principles of construction, can only be laid on their sides, yet ton for ton of material used, the tile designed to be laid in end construction show the greater strength.

The greatest argument in favor of end construction applied to buildings and other similar structures, is found in the fact that in tile-floor construction carrying heavy loads, end construction is always specified, and when side construction skewbacks and keys are called for, then the carrying capacity of that floor is reduced because the floor will fail (as has been shown by tests) by the side-construction key or skewback crushing before any of the voussoirs which were laid in end construction.

VIRGIL G. MARANI.
Cleveland, Ohio, Nov. 18, 1912.

## Notes and Queries

Information is asked by a correspondent, a designing hydro-electric engineer, on raft-chutes in dams. The problem is the design of a by-pass capable of passing rafts say 3 ft. deep x20 ft. wide x70 ft. long. So far the only data obtainable have referred to log chutes for handling individual logs.

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*Illustrated.

# Engineering News

## Concerning Smoking on Street Cars

An engineer who has supervision of the street-railway service in a large Western city writes requesting us "to prepare a strong editorial in ENGINEERING NEWS concerning the prohibition of smoking on street cars." Unfortunately he does not specify whether he is in favor of or opposed to such prohibition, nor do we know whether he himself is a smoker or not.

It is safe to say, however, that all passenger-traffic managers of either electric or steam railways would be greatly relieved if they did not have to make provision for smokers in public conveyances. The necessity for providing separate cars or separate compartments for smokers and non-smokers is universally accepted on steam railways as an operating necessity, but it makes necessary an annual expense aggregating millions of dollars, taking the country as a whole. The principle involved is the same as the separation of different classes of traffic, which, as is well known, is one of the reasons why European railways run a large percentage of their passenger trains only partially filled, or, to use the power-station term, with a small load factor.

So far as prohibition of smoking on street cars is concerned, it would be difficult to make any general statement as to the trend of practice. On elevated and subway trains where dense crowding is apt to be the rule, smoking is generally prohibited. In general, about the only places where smoking is permitted on street railways are on the rear seats of open cars, or on the upper deck of double-deck cars. Permission for those standing on the car platforms to smoke is gradually being done away with. It has a tendency to crowd the platforms and make passing in and out of the car difficult, and it also increases the liability to personal injury in case of collision.

## The Panama Canal Act and the Marine Equipment Industry

One of the most deplorable tendencies in recent Congressional legislation is the increasing custom of introducing in a bill legislation on some subject remote from the main purpose from that of the bill. The objections to legislation in this manner are so obvious and so serious that in some states constitutional provisions are in force, under which no legislation may be enacted on subjects not included in the title of the bill. Congress, however, is under no restrictions of this sort, either of law or custom; and in recent years a good share of the legislation it has enacted has been in the form of riders tacked onto appropriation bills. The same principle is now being carried into other legislation, and a notable example is the so called free equipment clause in the Panama Canal Bill enacted last August.

The clause referred to in this bill provides that materials for the construction and equipment of vessels of American registry operated through the Panama Canal and for the machinery of such vessels may be admitted free of duty, subject to regulations to be fixed by the Secretary of the Treasury.

Ever since the bill became law, there has been active discussion as to how this clause should be interpreted. On the one hand, it was contended that anything whatever for the equipment of a vessel or its construction; for example, complete marine engines, could be brought into the United States free of duty. This, however, has generally been felt to be an extreme interpretation; and from the language of the act, it is probable that what Congress meant to do was to admit free raw materials to be used in hull or machinery construction or repair.

Apparently there has been some conflict among the officers of the administration itself as to which interpretation should be placed upon the law. It was at one time authoritatively stated that the official interpretation was to be that anything for a vessel's equipment, no matter how complete its manufacture, could be admitted free of duty. In response to an almost universal protest from the shipbuilding industry, however, this extreme view has now been modified.

Whatever views one may hold as to tariff rates on foreign importations, it will be generally conceded that tariff protection to an industry should not be wiped out entirely at a single blow. President-elect Wilson himself is on record as declaring that in making needed reductions of the tariff, care should be taken to avoid injury to established industries while reducing excessive tariff rates in industries where American manufacturers are already able to compete with those abroad.

In the shipbuilding and ship-equipping industry, however, the United States is admittedly far behind England and Germany. There are American industries in which American machinery is sent all over the world in competition with foreign makers; but the builders of Ameri-

can ship machinery are confined to the comparatively narrow and limited home market and are as unable to compete on equal basis with foreign manufacturers as foreign makers of automobiles would be to send their products here in competition with the great factories of Michigan. There is good ground for believing, therefore, that wise counsels will prevail in the interpretation of the free equipment clause of the Panama Act, not only during the present administration but during the one soon to take office.

## Relieving Road Contractors of Liability for Patent Infringement

The question of possible patent infringements and royalty suits comes up in contract work often enough to worry contractors greatly. The usual procedure in specifying and contract letting puts the entire burden of risk from possible infringement suit upon the contractor, he being required to hold the owner harmless against any suit. In consequence, when there is any doubtful patent complication in the situation, the owner (or in the case of municipal work the public) must pay an excessive price because the contractor must bid high in order to be safe.

A very sensible change in this procedure has been made in California in connection with highway construction, by the California Highway Commission. This is set forth fully and clearly in a short article printed in the *California Highway Bulletin* of Oct. 15, 1912, as follows:

> The position of the California Highway Commission is that if there are any royalties to be paid for the use of any pavement or pavement processes in the construction of the state highways, the state will assume the responsibility, if the courts shall determine that the use of such pavements or processes is subject to claims for royalties under valid patents, and if the state by such use has committed a tort for which it is liable.
>
> The policy of the United States Patent Office, in issuing letters patent for road types and processes so freely and with so little apparent discrimination, has resulted in much confusion. These patents are so numerous and conflicting in their claims that neither the contractors nor the engineers are ever sure of doing their work unharassed by claims of alleged patentees.
>
> The immediate result of this turmoil and uncertainty is that the people in many instances pay more than is right for their roads and streets. In self-defence, the contractor must bid sufficiently high so as to protect himself against embarrassment if he is called upon to defend himself against claims for royalties, even if he believes that the work for which proposals are asked does not infringe upon any valid patent.
>
> Often a suspicion exists that both the contractors and the persons claiming patents are increasing their incomes unduly at the cost of the people.
>
> The Commission is of the opinion that if royalties must be paid, it will show better in the final analysis if such royalties are paid directly from the public treasury.

The procedure just described does not, of course, remove all troublesome features from the situation. The evils growing from the tangled patent conditions, well characterized in the above article, are not done away with when the state authorities assume the burden of defending suits and paying royalties or damages; but in most cases the difficulties are shifted to parties much better able to bear the burden of defending a suit than the contractor, whose attention should be confined to doing his work well according to his contract. Anything that simplifies contracting and tends to make it less of a gambling enterprise and more of a legitimate business should be commended.

## The Micrometer Applied to Brick Pavements

Mr. J. E. Howard's success in elevating the brick pavement to the rank of an engineering structure—possessing continuity, elasticity, and such other qualities that its behavior under different physical conditions can be predicted — gives ground for hoping even greater things in the future. There is a dim prospect that in time even the humble macadam roadway surface may be found to have a section modulus, a coefficient of elasticity, thermal expansion, and an elastic limit. When that time comes it will be very much easier to write technical literature on macadam pavements, though probably there will still be the present difficulty in making such pavements stand the wear of automobile traffic.

In the case of the brick pavement, fortunately, the Cleveland tests are not of merely abstract interest, but have a very definite meaning and lead directly to proper construction. The investigation is a classic; the successful application of the micrometer strain-gage to this delicate subject of study, no less than the clear and consistent results obtained, entitle it to such estimation. A beginning has been made in searching into pavement problems, and a way pointed for future work.

We now have clearly before us the conception of a brick pavement as an ever-moving layer of material. The pavement is not dead matter which, once laid down, is disturbed only when forced out of place after traffic loosens it from its bond or when removed for repaving. On the contrary, it is like the arch, which never sleeps. Let the engineer who designs pavements get the full realization of the fact that a system of brick pavements is in constant movement and change of form as the temperature rises and falls—he will unquestionably look upon his layout with a different eye and will constantly endeavor in his work to plan the pavement system for minimum effect of the temperature movements.

The micrometer investigations also reveal the fact that brick pavements are elastic. A local load, even a footstep, compresses the pavement and produces a local depression extending a surprisingly large distance in either direction. The connection of pavement and street-car rails makes both elements of the structure share the load applied to either. It is clearly very important that in a high-class pavement a high-class track construction be required. How many street-car franchises today insure in any manner that pavement and track will be properly coördinated? The common practice of giving over to the street-railway company the maintenance of paving within the limits of its track is certainly of no help in connection with the actions which may be deduced from Mr. Howard's studies.

The longitudinal elastic effect of the pavement means that it exerts great horizontal pressures. The attempt to resist these pressures by any kind of curbing ordinarily practicable is bound to be futile. Continuous stretches of paving or areas of paving can absorb the pressures, by their bottom friction, but at free ends it is necessary to allow the elastic forces to expend themselves in expansion.

The disturbances introduced by sudden elevations in the contour of the pavement, by the embedment of catch-basins and other foreign structures, by lateral roadways, etc., must hereafter have careful consideration. Whether the pavement's deficiency of longitudinal tensile strength as compared with its high compressive resistance can be compensated for by reinforcement may perhaps also be considered.

The observations recorded by Mr. Howard will require to be weighed and evaluated by paving engineers. The conclusions indicated in the article itself are suggestive, but they probably were not intended to represent the full practical yield of the experimental work. The testing engineer cannot be expected to furnish, besides his observation results, also their digest and conclusions; in fact, whenever he sets about his experiments with the expectation that he must also work up the results into conclusions, he prejudices his experimental work by a mental bias. The conclusions must come from the outside, in this case from the technical paving men. These men, whose work in designing pavements has heretofore been based only on general considerations and indefinitely measured experience, can now, for the first time, study the subject by the aid of quantitative experimental records.

## Rail Corrugation

A peculiar form of rail wear in which a series of waves or corrugations is formed along the rail head, has been noted abroad for many years, both on steam railways and street railways. In this country it seems to have occurred to a very limited extent (if at all) on steam railways, but within the past few years it has become a very serious trouble and a very insistent problem on many street railway systems and the problem of remedying it has become pressing. In some cases it has been so serious as to increase the cost of maintenance of cars and to produce a noise extremely annoying and objectionable to people living along the line. Under such conditions, engineers have been compelled to make careful investigations as to the cause and to devise some means of remedy. Elsewhere in this issue we describe some of the troubles experienced in Chicago, where there has been much trouble of this kind and where extensive work has been done in remedying these troubles by grinding the rails in the track so as to give a new and smooth running surface.

The causes of rail corrugation are still a matter of controversy, both in this country and abroad. Numerous causes have been suggested and theories advanced, many of which probably have more or less influence either generally or locally. In the Chicago investigations, however, the principal contributing causes seem to include three features of track condition which develop trouble under the large and heavy cars operated. These are as follows: 1, a very rigid base or foundation; 2, irregularity of gage; 3, rails loose upon the ties or base, and held tightly only at irregular distances (this condition is accentuated where welded joints connect the rails into long stretches).

As to the first cause mentioned, a concrete base was used extensively in the reconstruction of the street-railway lines, but a bed of stone ballast is now considered preferable as affording some elasticity and reducing the liability of corrugation of the rails. As to the second cause, it is claimed that the long stretches of 9-in. 129-lb. rails buckle vertically under the influence of high temperature and exert sufficient force to loosen or even break the fastenings to the ties. At certain irregular distances and places the fastenings may continue to hold the rail securely, and the result is that the heavy cars batter the loose part of the rail upon the foundation. In regard to the third cause, the engineers of one of the Chicago lines consider that irregularity of gage (and especially tight gage) of the rails has a good deal to do with the trouble. Under ordinary conditions of track construction the tie-rods are put on and adjusted by men who have no understanding of the importance of exact adjustment, and the gage is likely to be tested only at long intervals. It is suggested that much more care should be taken in setting up and adjusting the tie-rods, and that the gage should be tested and adjusted much more frequently.

As rigid track construction for street railways has been used very extensively for many years in Europe, and as rail corrugation on such lines is a comparatively modern trouble which has developed to serious proportions within the past few years, it seems evident that the heavy cars and high speeds of modern electric street railways form influential factors in the problem. These conditions of weight and speed are specially severe in this country, and may be considered as factors which cannot be eliminated. One line of remedy, therefore, seems to lie in a substantial and carefully constructed system of track. If it is found impossible to hold the rails absolutely tight upon the ties or base, this track system must embody some elasticity to avoid a pounding action in which the wheels beat the rails upon the rigid base as upon an anvil.

On roads where this trouble has developed to a serious degree it is now increasingly common to grind off the corrugations, by means of a machine operating on the track. This is expensive, however, and it would be of great advantage could some means be found of preventing the development of this character of rail wear.

One of the many causes of rail corrugation that have been suggested is the action of car trucks under the influence of brakes, but on the Chicago lines it is found that corrugation does not occur at points where brakes are applied. Besides this, the corrugation often extends for considerable distances, while the effects of braking and acceleration would be local. On the other hand, it seems very certain that the truck and wheels play an important part in producing and developing rail corrugation; this is due to causes both in the truck itself and in the track upon which it rides, as noted below.

An incipient corrugation in the rails as they come from the mills is another theory, the idea being that in the manufacture of the rails a slight vertical play of the rolls causes a vibration or "chattering," which gives in effect a series of sharp intermittent blows on the rails, thus causing hard spots. But careful observation in Chicago shows that in rails of the same lot and from the same ingot some will develop corrugation and others (in the same track) will remain free from the trouble.

This theory of inherent defects in the rails is given much greater weight in Europe. At Berlin, grooved-girder rails only 4 in. high are being used, as shallow and comparatively flexible rails are believed to be less liable to defects causing corrugation than are the deep and rigid rails.

In a report presented at the annual meeting of the International Street and Light Railway Association, at Christiania (Norway), in July, it was stated that the companies at Hamburg and Lyons considered the rolling of the rails to be responsible for the trouble. The Hamburg company believes that the tendency to corrugation is increased in two ways: 1, when the number of passes is large, especially during the formation of the groove, when the change in shape is rapid; 2, when the steel has a high tensile strength and a low modulus of elasticity. The Lyons company reported having noticed corrugation on new rails from different mills, and attributed this to lack of homogenous character of the metal and to the methods of rolling the groove. It suggested that an effort should be made to insure greater uniformity of temperature throughout the steel, and greater uniformity of pressure in the rolling mill.

Some street railways in Europe are trying rails having diagonal slots cut in the web during rolling, as a means of checking vibration due to the rolls. We are inclined to think, however, that the evidence is far from sufficient to indicate that the manufacture of the rails is anything more than one of many possible contributory causes of rail corrugation, except in some special cases.

An investigation of the problem of rail corrugation has been in progress for some time by a committee of the Municipal Tramways Association of Great Britain, and has included practical tests as well as an analysis of conditions and theories. In a preliminary report made at the recent annual meeting of the association some conclusions were presented which, while largely of a negative character, are of interest in giving some definite statements. For one thing, they appear to sustain the claims that traffic, brake applications and rail manufacture are not contributing factors of importance in this very complicated difficulty. The following is a summary of these conclusions.

**Corrugation occurs very widely on systems with electrically self-propelled rolling stock, the construction of which necessitates a relatively low center of gravity; also on cable systems, and to a relatively small extent on steam railways.**

**The check or guard of the rail is not a necessary factor in causing corrugation.**

**On almost every system it occurs abundantly at places where the brake is very seldom applied, and is not any more frequent or pronounced at places where the brakes are regularly applied, as at stopping places. It may be concluded**

that the great bulk of corrugation is not due to any action of the brake.

Its occurrence is not dependent on the number of cars which have passed over the rails.

It is not necessary that the track or the rolling stock or the wheel profiles should be in a worn or defective condition in order to produce corrugation. With all these factors in excellent conditions, a car traveling with power under ordinary conditions will readily produce corrugation.

Corrugation appears on the rails independently of whether the wheels are being actively driven by the motors or not. The explanation of this may be the slip and skid taking place owing to the different diameters of the wheels, which difference largely results from the unequal wear produced by the relative difference in speed of the two motors.

Corrugation produced by one set of cars may be entirely removed by another set of cars running in place of the first. It may also be caused and removed by the same set of cars under apparently the same conditions.

The pitch of corrugation is independent of the speed of the cars producing the same.

Corrugation does not exist on street railway rails as received from the rolling mills.

Corrugation has been produced by every known type of electric car, and the pitch and characteristics are independent of the type of such car producing the corrugation.

It is suggested that the brightness of the crests of corrugation, as compared with the comparative dullness of the hollows, is due to a purely rolling action under increased pressure over the crests, and that other portions of the rail are not subjected to a purely rolling motion, but to the action of slipping or skidding, alternating with the rolling motion; hence their dull appearance.

A careful discussion of this question, based largely on investigations on the Chicago lines, was presented by C. K. Mohler in our issue of Nov. 30, 1911. He arrived at the conclusion that the trouble was due in the main to a combination of longitudinal and lateral slip of the wheels upon the rails, the slipping being caused by vibration of the gearing, defects in track, and a tendency of the axles to take a position diagonal to the rails. We summarize his views on this point, as relating to straight track, as follows:

When for any reason the flange of the wheel is brought in close contact with the guard of the grooved rail, there is a tendency for that wheel to rotate on the larger diameter of the flange. Then the axle tends to take a diagonal position on the track, which is easily accomplished on account of the lost motion and play between the axle, journal and frame. As soon as the wheels roll at an angle to the longitudinal axis of the track, transverse slipping on the rails takes place. While the guard of the rail is a very active factor in the production of corrugation, it is not wholly responsible, as this trouble often develops where there is no such flange contact. Soft spots in the track, low joints, uneven surface and variations in gage may be responsible for starting corrugation under the tendency of the propelling axle and wheels to take and maintain a position diagonal to the track. The vibration of the motor gear is probably instrumental in causing initial slipping at critical points. The presence of grit and mud on the rail is another factor. The tendency of the truck to oscillate or "nose" from side to side is still another.

Finally, we may say that the bulk of experience in this country and abroad points to a combination of two causes for rail corrugation: 1, defective features of track construction (independent of the character of the rail); 2, irregular motion of the truck and wheels. We do not find that any previous investigation has touched more than incidentally upon the question of gage of track, which (as noted above) appears to be an important factor of the trouble on the Chicago lines. It is easy to realize that an intermittent resistance to the wheels caused by variations in gage and surface, would result in a checking and slipping of the wheels and consequently in a vibration and nosing of the truck. These particular defects in track would explain, also, why the trouble occurs extensively on tangents, where theoretically the wheels should roll freely, and is not confined to curves, where some checking of the wheel motion is to be expected. For an effective remedy it would seem to be necessary to consider both the track and the car; the first in order to eliminate defects which may tend to affect or interrupt the free motion of the wheels; the second in order to devise a construction which will minimize any inherent tendency of the truck (or its axles) to assume a position diagonal to the track.

## Intimate Glimpses of an Engineer's Life

(CONTRIBUTED)

Occasionally a man will pass through a life of great achievements and get not even passing notice, while another will find himself the object of much public attention, laudatory or condemnatory, for doings of much less moment; and this, too, without any endeavor for publicity on his part. While this is true in all walks of life, it seems doubly so in engineering.

Twenty-seven years ago John Hislop, a sturdy young Canadian and a graduate of McGill University, made his way to Denver, Colo., and shortly after joined a party of surveyors bound for Berthoud's Pass. He was an ideal axeman and a good fellow generally in spite of his abnormal reserve. His communications were scarcely more than yea, yea and nay, nay, and yet his eye had a genial gleam and his hand was ever ready to assist.

Theoretically and to the uninitiated it is a picnic to be roaming through the mountains in the summer, pitching tents here and there in picturesque spots with a wilderness of wild flowers blooming on every hand and luscious little strawberries growing in red clustered profusion wherever one may turn. The altitude and the gentle breezes prevent discomfort from the heat and all in all the conditions are apparently most favorable for an agreeable outing.

But there are other considerations in the case of a surveying party on rush work—and when is a railway-locating party not rushed more or less—for the day's work may be from dawn to dark and the day's notes must be shaped up by candle light. The profile of the line is a succession of saw teeth, a graphic exhibit of the climbing and sliding of the party up and down the steep slopes of the deep ravines. A tooth or two may be missing now and then and this may represent a swamp, for the swamp is a common feature of the mountain landscape.

Parties were smaller in those days than now, and with the constant mishaps they were always short-handed. When the leveler was down with scarlet fever, the topographer prostrate with a malarial attack, a little rheumatism going the rounds, an occasional cut or sprain, an able-bodied man like Hislop helped wonderfully to keep up the tone of the party. He invariably took the heavy end quietly and effectively.

After three months of this bracing life, the party was fairly well acclimated and reasonably worn out; but change of work and scene is rest, and the welcome detail to the banks of the upper Mississippi to assist in the construction of the Burlington R.R. from St. Paul to Chicago was joyously appreciated by one and all.

Hislop now began to silently garner the fruits of construction experience, for he never wavered in his determination to make good as an engineer. But the railway engineer is here today and there tomorrow, strenuously at work for a few months now, and then hunting for another job. Hislop drifted back to Denver in May, 1889, and there joined a party for the conquest of the Colorado River, a year's work which proved his courage and efficiency beyond all question.

From the junction of the Grand and the Green Rivers to the Gulf of California, 1200 miles, half the way through deep cañons, flows the Colorado, its treacherous surface sunk in places to a depth of more than a mile below the level of the surrounding country. Its bed may be likened in a general way to a giant's staircase, a flight of over 500 steps. There are more than 500 falls or rapid stretches in its course through the cañons. Could risers and treads be equalized they would be about 12 ft. and

one mile, respectively, a nice easy descent for something less than seven-league boots. But turn on the water and set mere man afloat along its alternate sluggish and turbulent stretches and what is the result? In five weeks a party of sixteen men in six boats is done for. Loss of provisions and utensils, wreck of boats, disaster, desertions and death. One man, the head of the enterprise, lost in a whirlpool and two others dashed to eternity in the seething rapids.

The remnants of the party returned to Denver to refit. In six months they were again in the troubled waters of Marble Cañon, with light unsinkable boats, long safety lines, life belts, water-tight provision bags; and the boats were navigated now with skill born of experience. This party contained twelve men and three boats. In four months, seven men and two boats reached the Gulf of California, one boat having been converted to splinters on the way. It was nothing unusual for a man in a life belt to be spilled overboard and bobbed about in the foaming current until such time as he could make arrangements for a more dignified progress. (For details of these adventures see the articles by Robert B. Stanton, the engineer in charge of the party; *Scribner's Magazine,* November, 1890, *Trans.* Am. Soc. C. E., Vol. XXVI, 1892, and ENG. NEWS, Oct. 18 and 25, 1890.)

What was Hislop's record on this trip? The "wiry athlete" of the scaling party, the expert handler of instruments, the "sturdy helmsman." "No one could have rendered more faithful service or have more skillfully saved our lives by his quick-witted work just in the nick of time, than my first assistant, John Hislop," writes Mr. Stanton.

However, in the spring of 1890, Hislop was again out of a job. For a while he was on irrigation work in Idaho. The Klondike excitement probably attracted him to Alaska. He may have gone over Chilkoot Pass with the pioneers. In any event, he had charge of the construction of the White Pass & Yukon R.R., 110 miles, requiring the most expert work under no ordinary conditions, between Skagway and the interior. By way of recreation he served as Mayor of the City of Skagway. On his return to the scene of his early labors to marry the girl who had been waiting for him a dozen or more years, he seemed to be the same old John as ever, calm and beaming and generally reticent as to his achievements.

That such a man, so strong, so well poised, so inured to contingencies requiring athletic skill and coolness, should have fallen beneath the wheels of a moving train, while swinging himself aboard seems hardly creditable. Yet his life was cut off in this manner in February, 1901, but a short time after his marriage and while still in the prime of life.

## Nature and Conduct of the Slides in the Culebra Cut*

The slides in the Culebra Cut are attributable to two general causes:

(a) A primal cause, the weak and unstable geological condition of the rocks throughout which the Cut passes, attributable only to nature; and:

(b) The oversteepness and height of the slopes, the blasting, and other work attributable only to man.

All of the Isthmian sedimentary rocks are cut by intrusions of basic lava, mostly basalt, and by plugs of meta-breccia, pushed up cold by some of the lava intrusions. The lavas and breccias are strong, but most of the sedimentary rocks of Culebra Cut are uncrystallized, loosely cemented, sheared, and cut by fissures and faults, so they are very weak and unstable. Through their interstices and joint and fault planes, they absorb a large amount of the heavy tropical rains, which further weakens them, and which increases their tendency to deform and slide.

There are four distinct types of slide, as follows:

(a) Structural breaks and deformations resulting in slides.

(b) Normal or gravity slides.

(c) Fault zone slides.

(d) Weathering and surface erosion.

The structural break and deformation slides are the most troublesome and most important. Their first manifestations are cracks or fissures, approximately parallel to the side of the Cut, and from a few to a hundred yards, or more, back from it, and from each other. Each fissure is usually traceable on the surface for several hundred yards, and each gradually widens with time. The next stage of this type of slide is the tilting of the large blocks, toward the Canal, usually accompanied by upward bulging of the bottom of the Cut, opposite the moving block. For a few weeks, or even for a year, or more, this tilting, settling, and bulging may continue before the real slide comes. This last stage consists in the collapse of the basal part of a moving block, due to the pressure of its upper part, and to the weakening effects of the deforming and shearing movement that it has undergone. When this stage is reached, the block rapidly disintegrates, and, in a few hours, or a few days, it becomes a gravity slide of mud and rock débris piling up at the bottom of the Cut.

Normal, or gravity slides, occur where the Cut intersects beds of porous material lying on top of relatively impervious clay, shale beds, or dense lava masses. Water sinking freely through the upper bed is retarded in its descent by the impervious material, and thus causes a muddy, slippery zone to form along the contact between the pervious upper and impervious lower layers. If the latter dip toward the Canal, or if there is much lateral pressure from higher ground, the material above the zone of contact is almost sure to slide. The Cucaracha and Paraiso slides are of this type, but like most slides of this kind, they are now practically dead. This type of slide, it is predicted, will not, from now on, in the progress of the work, be of relatively large size of importance.

The fault zone slides are occasioned primarily by sheared and weakened zones in the rocks, due to fault displacements. Where fault planes are intersected by the plane of the Canal slope, large masses of rock in the acute angle between the two planes generally fall out into the excavation; or where the fault plane dips, the overhanging rocks—"hanging wall" of the plane—often crush down into the excavation. The most notable fault zone slides are the La Pita slide, and that about 600 ft. north of La Pita, which, on Aug. 20, 1912, in a few minutes, let down about 300,000 cu.yd. of material and carried away a hundred yards of the East Diversion.

The heavy tropical rains erode and trench the slopes and wash the weathered surface material into the Cut. Weathering and disintegration of most of the rocks of Culebra Cut is very rapid because the iron and magnesia compounds, which they contain, are readily oxidized on exposure to the atmosphere. The new oxides formed take up more room than the old product, and the change of volume thus brought about causes the rock to crumble and fall to pieces. These rocks also contain some soluble limy cementing material, which, when leached out by surface waters, helps along the disintegrating process. The loose surface product, which results from this rapid weathering, is swept from the slopes by the heavy tropical rains, and thus fresh surfaces are left exposed for further weathering action. Slopes that are clothed with a carpet of vegetation are relatively free from erosion, hence tropical vegetation will be encouraged to cover the slopes of the Canal with its abundant growth, that washing by tropical rains may be minimized.

The geologist believes that the rock conditions along the Canal will limit the slides within certain fairly definite bounds, and that when the slopes have been reduced to the proper angle, the slide problem will be practically solved. This angle will vary from almost perpendicular in the case of the strong lavas, to one on five for the weaker rocks, or even one on ten in a few extreme cases, where deformation and faulting have been pronounced. Slopes which have not moved will stand at a much steeper angle than those of the same material, which have been sheared, cracked, and bulged by deforming movements.

*A report of the Geologist of the Isthmian Canal Commission. From the "Canal Record," Nov. 16, 1912.

# A Concrete Block for Lining Shield Tunnels

The great cost of the cast-iron lining now in almost universal use for shield-driven tunnels has led to the design of a concrete-block tunnel lining by John F. O'Rourke, of the O'Rourke Engineering Construction Co., New York City. Shield-driven tunnels with masonry lining have been built in a few cases, but the difficulties involved in obtaining a firm abutment against which to work with the jacks that force the shield forward form a serious objection to such lining. The masonry (stone, brick or concrete) is, of course, not firmly set for a considerable distance back of the shield. The fundamental idea of the O'Rourke block is to bring the central parts of the blocks into abutting contact through projections seated in recesses, which permits of safely and reliably transmitting the full pressure of the jacks without risk of concentrating pressure on the edges of the blocks, and at the same time leaves a joint of such form and size as to allow of wedging for adjustment and give room for grouting or calking the joints. Incidentally, the projections and recesses in the ring-joint faces of the blocks, besides furnishing this direct contact of adjoining blocks, have the important effect of interlocking each ring of the block lining with the adjoining rings.

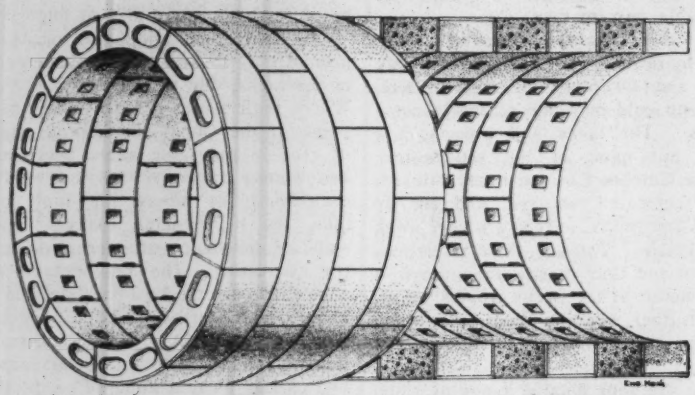

FIG. 1. SKETCH OF O'ROURKE CONCRETE-BLOCK TUNNEL LINING

The cut, Fig. 1, herewith shows in perspective a short length of tunnel made up with the O'Rourke block (not drawn from real life, however, as no tunnel has been built of these blocks up to the present). The lower illustration, Fig. 2, gives a drawing of the block itself in several elevations.

The O'Rourke lining consists of rings of constant length just as with cast-iron lining, each ring made up of a number of segmental blocks. No key section (as usual with cast-iron lining) is provided in the drawing shown, although it can readily be provided if desired. The longitudinal faces of the block are plain, but the transverse faces have projections and recesses which interlock. As the figures show, the forward face of each block has two slightly tapering recesses or depressions. The rear face of the block has corresponding projections. The projections of one block engage the recesses in the forward face of the next ring back.

Successive rings are to be set breaking joint, that is to say, a block in a given ring engages two blocks in the ring to the rear and in turn is engaged by two blocks in the ring ahead of it. This interlock gives the tunnel-shell bending strength (in circumferential direction). A single ring has no bending resistance whatever, but can act only as an arch; two adjoining interlocked rings, however, will have opposite each joint in one ring the solid body of the block in the other ring, and therefore possess a bending strength equivalent to half what would be obtained in monolithic construction.

The projections of the blocks are slightly longer than the depth of the recesses. When two blocks are fitted together they will be in contact at the bottom of the recess, but will not be in contact along the joint faces by a clearance of 1¼ in. Longitudinal pressure, such as that which is produced when the shield jacks operate, will therefore be transmitted from ring to ring of the lining by way of the projections of the blocks, instead of having to go through the filling of the joints.

All four joint faces of the block are surrounded at the outer edge by a raised bead of flat rounded contour, ½ in. high above the general plane of the joint face. The beads of adjoining blocks are intended to come within ¼ in. of touching, and this ¼ in. gap is to be sealed with tarred felt or other gasket, to make the tunnel tight against material pressing in from the outside. At a later stage of construction work, the 1¼-in. joint space behind the beads is to be filled with cement or any other filling or calking material.

In the case of the ring joints, the proper spacing of the adjoining blocks is assured by the projections and recesses which by coming into contact determine the 1¼-in. joint clearance and the ¼-in. bead clearance. The longitudinal joints between blocks of the same ring, will be spaced approximately by their interlock with the preceding ring, and can be regulated by wedges (as indicated in Fig. 1, and by sectional sketch in Fig. 2) in order to give the ¼-in. bead clearance and 1¼-in. joint clearance. The use of these wedges also permits of adjusting the shape of the ring to a true circle.

Dovetail recesses on the inner face of each block, as shown, serve for gripping the block with the lining-erector (as used in setting cast-iron lining), which sets the blocks in place. These recesses may be used for connecting one ring to another with cramps, for the same purposes as served by bolts in cast-iron lining, either temporarily or permanently.

The blocks as at present designed contain no metal reinforcement, but it is understood that this can be added when desired.

A patent was issued to Mr. O'Rourke, Nov. 5, 1912, on the block described and tunnel lining built of such blocks. The patent covers also blocks in which both front and rear face are recessed, to receive dowels made separately. The blocks may also be used for sewers and conduits built in open trench.

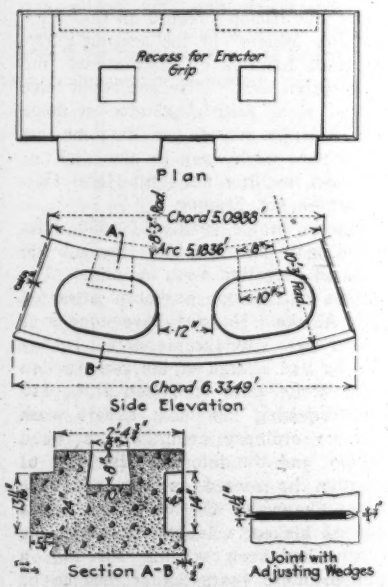


FIG. 2. THE O'ROURKE TUNNEL-LINING BLOCK

Cheapness and rigidity of tunnel-shell are among the principal claims of advantage made for the O'Rourke blocks. Mainly on the former claim, the use of these blocks in the new East River tunnels to be built for the new subways in New York City has been proposed to the Public Service Commission.

# The Sandblast vs. the Rattler Test for Paving Bricks

In the *Transactions* of the American Ceramic Society, Vol. 14, which has recently been published, Prof. Edward Orton, Jr., of Ohio State University, presents a paper comparing the effects upon paving bricks of the standard rattler test and a newly proposed sandblast test. The rattler test has been adopted by the American Society for Testing Materials and the National Paving Brick Manufacturers' Association. It consists in measuring the abrasion caused to a brick by revolving it in an irregularly shaped metal box. The sandblast test has been proposed as a substitute for the rattler test on several occasions, notably, according to Professor Orton, at the 1909 annual meeting of the American Society for Testing Materials before the meeting of Committee $C_3$, however, and not before the Society's open session. It consists in noting and measuring the size and character of the abrasion caused to the surface of a brick by a stream of sand forced by compressed air against a limited area of the brick.

Professor Orton, in connection with the Pittsburgh laboratory of the U. S. Bureau of Standards, made in 1911 a series of comparative tests of the two methods on the same bricks. The sandblast equipment consisted of a sandblast machine for driving the sand and a closed cabinet provided with a rotating shaft on which the specimen was mounted opposite the nozzle of the sandblast. The brick to be tested was placed in a clamp on this shaft, covered with a steel template clamped to the brick with a rubber gasket which affords a soft bearing and prevents the brick from slipping, leaving a circular opening 6 cm. in diameter exposed to the blast. The sand was conveyed from the injector through a 1¼-in. rubber hose, and a ½-in. cast-iron, case-hardened nozzle. A shield, which could be dropped in front of the blast, permitted the starting and stopping of the cutting at fixed intervals.

The type of sand used gave considerable trouble at first. It was the original intention to use the standard Ottawa sand obtained by screening through a 20-mesh screen, and again on a 60-mesh screen, using that which had passed the first and lodged on the second. After use this was to be rescreened between 20 and 60 mesh and a mechanical analysis run and compared with the original. If the mean size was found to be finer, it was to be toned up with new sand of 20-30-mesh grade from the original source of supply. This scheme did not prove successful in practice because of the difficulty of restoring the sand to its original granular condition. Further tests showed that the sizes of the sand had a very serious effect upon the rapidity with which the blast cut into a specimen, but finally it was decided to use standard Ottawa sand screened between 20 and 30 mesh and running the blast for three minutes. After each run, the sand was screened again to take out the fine grains resulting from the process.

The final conditions, then, of the sandblast test were as follows:

Sand—Ottawa Silica Co.'s 20-30 mesh—sifted after every test.

Sand valve—$\frac{7}{16}$ hole in diaphragm—stopper raised $\frac{3}{8}$ in.

Sand nozzle—½ in. in diameter—changed when it wore to $\frac{11}{16}$ in.

Air pressure—20 lb. per sq.in.

Area attacked—circle 6 cm. in diameter.

Distance between nozzle and brick—12 in.

Duration of test—3 minutes.

Losses compared by loss of weight in grams.

## RESULTS OF THE TESTS

The bricks upon which the sand blast tests were carried out comprised 58 different lots, all of which had been previously tested by the rattler process. Of these 58 samples, 41 were paving blocks, and the 17 remaining were building bricks. They naturally showed various degrees of wear. In the case of the better grade of paving blocks, where the rattler losses had not exceeded 20 or 22%, the individual bricks had lost corners and edges pretty generally, but retained plenty of surfaces upon which the 6 cm. perforated template would fit snugly. In the case of some of the softest paving blocks and the majority of the paving blocks, the surfaces were worn rounding, so that the template could not obtain a uniformly flat bearing. The sand did not leak around the edges of the template in these cases and cause increased wear. The edges of the holes were sharp after the test. The only inequality, therefore, between those bricks which presented a virtually flat surface for attack and those of rounded surface was the slightly different distances between the different parts of the latter and the nozzle of the sandblast. It is not believed that these distances vary enough to make any sensible difference, and any such that existed would probably be in favor of the rounded bricks, instead of against them.

From each of the 58 lots of brick represented by two charges of 10 each, or 20 individual bricks, three bricks were selected for the sandblast test. They represented one of the harder bricks, one of the softer ones, and one seeming to represent the average. It would, of course, have been preferable to apply the sandblast test to all of the bricks of each charge, to get a more perfect comparison and better averages, but this would have made the test too costly. As it was actually put through, about 200 sandblast tests were made. All paving blocks were tested upon the edge or surface which would be exposed to wear in the street if used as pavers, except where so badly worn that no suitable area could be found on the edge. Building bricks were tested on the side instead of the edge.

The sandblast cuts, with astonishing rapidity, into any ceramic material. The rate of cutting, however, varies very widely. In general, the action is slowest on dense, fine-grained or amorphous, hard bodies like glass, and most rapid in porous, granular, soft bodies like mortar or soft burnt clay wares. As a mode of exposing the extent to which the constituent parts of a clay body are bound together into a silicate matrix, it is unrivaled. To a considerable extent also, it is of use in developing the flaws, structural defects, laminations, lack of homogeneity, etc., in a clay body, for it cuts faster into all defects than into the solid portions.

A large table accompanies the report, giving the detailed behavior of 183 specimens under both the rattler and the sandblast tests. These are abstracted in the table herewith, which groups the samples in four groups. This table gives the

TABLE SHOWING RELATIVE ABRASION FROM RATTLER AND SANDBLAST

| | Aver. Rattler loss % | Aver. Sandblast loss % | Ratio |
|---|---|---|---|
| 1st ten samples..... | 17.34 | 71.5 | 4.12 |
| 2d ten samples..... | 20.61 | 82.5 | 4.00 |
| 3rd ten samples..... | 23.53 | 89.9 | 3.82 |
| 4th eleven samples..... | 29.84 | 97.6 | 3.27 |

average losses under each of the two tests. There are a large number of instances where the two processes check quite closely. Out of 41 comparisons about 30 give good checks. The other 11 or 12 comparisons are glaringly out of concordance and the way in which both methods were able to check themselves shows that their failure to check each other is not accidental. Professor Orton states that the data seems to prove that the combination of properties which enables the paving brick to withstand the rattler test creditably will in general enable it to withstand the sandblast test creditably. He then gives some 11 samples which vary from the average and explains why the particular specimens should be out of the ordinary. He further states that:

These cases seem to the writer to clearly show the fun amental differences in action of the rattler test and the sandblast test. The first set of bricks will stand the former and will not stand the latter, because the bricks are tough, but are either not very hard or else have numerous soft spots scattered through a hard matrix. The second set of bricks will stand the latter and not the former, because they are hard, vitreous and glassy in texture, but are brittle or defective in mechanical structure or both.

In short, the sandblast really measures hardness and not toughness, i.e., glass would resist sandblasting exceptionally well, but it would not resist rattling at all well. And while it is true that in general the better grades of paving bricks do become increasingly hard as they vitrify and at the end are both tough and hard, it is equally well known that many clays which burn to a very hard body, of glassy texture, are very weak and brittle when subjected to blows. Hence, it is clear that in any large number of comparisons of the two processes, we should expect to find just what we do find, viz., general concordance between the results of the two tests, but, nevertheless, frequent and wide departures from concordance.

The conclusions of the report are as follows:

It should be borne in mind, that in seeking to make a comparison between the values of these two methods, we cannot set aside the fact that the rattler test has, by a continuous usage of over 20 years, and a somewhat careful and fairly well standardized usage of at least 10 years, established itself as a criterion, while the sandblast has no such standing. Rattler tests have been made to the number of many thousands, by many hundreds of engineers to whom the results have come to offer an intelligible meaing. It is possible to some extent to interpret rattler data into wearing value in street use.

The rattler process started with the absorption test, the cross-breaking test, the crushing test, the specific gravity test, the hammer test, the frost test, the grinding-table test, and perhaps some others; but it has outlived them all, and remains today practically the only test used. All the others have either disappeared wholly from use in estimating paving material, or are used in a sporadic case here and there.

In interpreting rattler data, there is still room for honest difference of opinion. It is agreed very generally among engineers and brick manufacturers that the rattler test is a severe one, and that any brick which can endure this test creditably will with absolute certainty give a good account of itself in street use, if properly laid. The best bricks in the world will make a wretched street if not properly laid, but such failures are not chargeable to the bricks themselves. On the other hand, it is by no means agreed just where to draw the line between permissible and nonpermissible rattler losses, or to say just how good a material must be or how poor it dare be and still justify use in a street.

It has long been recognized that the rattler measures toughness, i.e., ability to withstand blows and friction, better than any other device. No one can really say what makes one rock tough and another brittle. It is not wholly a function of hardness, certainly, because any very hard bricks are brittle, and yet, hardness enters into it. It is not a matter of crushing strength, for many dry-press bricks show phenomenal crushing strength, but no dry-press brick rattles well. It is not wholly a matter of elasticity, for glass, one of the most brittle of solids, is very elastic indeed, and yet, a lack of elasticity would surely be against the development of toughness. Whatever toughness may be, or may not be, it is the one quality or combination of qualities needful above all others in good paving bricks.

On the other hand, the sandblast test does not bring out by any kind of shock or other means the presence or absence of toughness. Its blows are infinitesimally little, but also infinitely numerous. They wear away, not by a blow, but by scouring.

Any hard body, be it brittle or tough, is able to make a good showing in such a test. Hence the answer of the sandblast in any given cause, unless supported by supplementary data, gives no assurance of toughness. Beyond a doubt, hardness in paving bricks is generally associated with toughness. In the present series, this is true in about 75% of the large number of samples tested. But, if the sandblast test gives a misleading decision in 25% of the cases in which it is used, how long can anyone depend upon it?

The test is like the rattler test in requiring the closest kind of adherence to an empirical standard of procedure. Every minute factor of both tests has its influence, and no one can get comparable data who does not conscientiously watch every one of these factors. The sandblast test has even more variables than the rattler. It would require more, rather than less, skill to use it. This is certainly against its use.

In point of time required, the sandblast test, if applied to a sufficient number of bricks to get reliable averages, would be much the longer. One blasting can be made in a few minutes, but to get a series of results involves cleaning out, readjusting, etc. It would increase the time required to give an answer as to a given material's fitness to be accepted —often a very urgent matter in street building. The readiness of the rattler is one of its strong points of advantage. In point of cost, the sandblast test would save nothing. The frequent renewal of nozzles, diaphragms, templates, gaskets, etc., the constant wearing out and restandardization of the sand supply, and the cost of making the compressed air, will surely counterbalance the larger use of power and the heavy wear and tear on staves and shot in the rattler process.

The country has facilities for the sandblast test in very few commercial establishments and in practically no testing laboratories. It would be a long time before the method could come into general use even if its advantages were obvious and weighty.

### SUMMARY

1. The sandblast method has no advantage on either technical or economic grounds over the rattler process as a mode of testing paving bricks for their resistance and wear.

2. The sandblast test measures hardness rather than strength or toughness, and while most good paving bricks are hard, it is entirely unsafe to make the hardness test criterion of their excellence.

3. The greatest value of the sandblast as a laboratory tool is its ability to expose the structure of strong bodies, natural or artificial. For this purpose it is unrivaled.

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**The Bagdad Railway** is now under operation for a distance of 150 mi., from Konia to Kishla, and for 90 mi., between Dorak and Mamouret. Work on the intervening lines is now in progress.

## Another Amateur Dam

The construction and inevitable destruction of another amateur dam has been brought to our attention by Charles Brossmann, consulting engineer, Indianapolis, Ind., in a communication from which we have abstracted the following account. The dam was built about three years ago and almost immediately failed. It has been since replaced, we understand, by another structure. The absolute ignorance of engineering principles displayed in its design, however, makes it an example which should be brought to the attention of the profession.

The dam was built for water-storage purposes for the water supply of the town of North Vernon, Ind., and is located a few miles above the pumping station on the Muscatatauk River. It was completed about the end of the year 1909 and went out in the first weeks of 1910, about a month after its completion. Figs. 1 and 2 show the design of the structure. It has a main rectangular section of concrete 3 ft. 6 in. wide and 8 ft. deep founded on rock, in the river section at least, and has a slight curve in plan upstream. The concrete section was reinforced at about the neutral axis of the rectangle with 1-in. twisted steel bars extending across the dam, and the base was tied to the rock bottom with iron dowels, the spacing of which was not

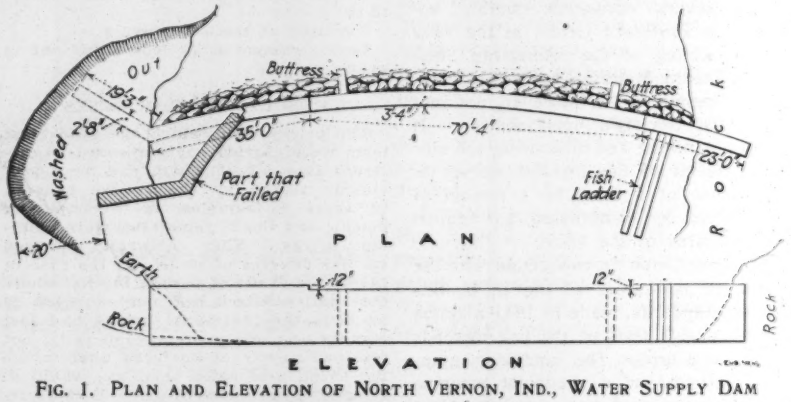


FIG. 1. PLAN AND ELEVATION OF NORTH VERNON, IND., WATER SUPPLY DAM WHICH FAILED IN 1910

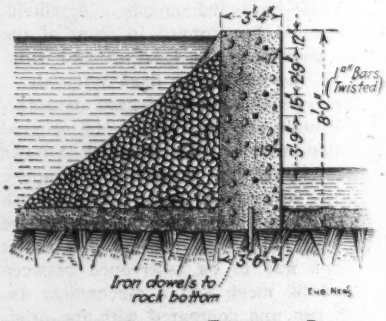


FIG. 2. SECTION THROUGH DAM
(Note upstream buttresses and rip-rap.)

specified. On the *upstream* side of the dam a riprap fill was placed as shown in the section, and in addition two triangular buttresses as shown in plan and in section were placed near the shore *and also on the upstream side*. A very narrow fish ladder on the downstream side near one shore provided a similar buttress on that side, and doubtless served to strengthen that end of the dam. One end of the dam continued in the plan of the arch curve into the earth of the bank and was founded on the same rock present in midstream. The other end, for some unaccountable reason, was given a reverse bend, somewhat in the nature of a wing wall. The design of the footings of this end is not available but, judging from the subsequent failure and the view in Fig. 5, the foundations were not carried down to rock.

Reports give the height of water going over the dam at time of failure at from 4 to 8 ft., though these figures are not verified. At any rate, the heavy current washed the earth out at the abutment which was turned inward, as shown on the plan, and shifted the entire end section there out to the position shown in Fig. 1. The three photographs reproduced as halftones herewith show the condition of the dam after failure, Figs. 3 and 4, showing the whole structure, and Fig. 5 showing the nature of the ground at the abutment which failed.

The design of this dam is so miserable as to be almost criminal. An arch dam with practically no rise to the arch and with abutments footed in soft clay, buttresses on the wrong side to resist pressure, and riprap added to the overturning pressure of the dam, all points to absolute ignorance of engineering principles. However, the town of North Vernon spent $1860 for this dam and paid $200 extra for the riprap. We are not informed as to the nature of the person or persons who were responsible for the design. We do understand, however, that the construction was very good and that the concrete seemed to be exceedingly hard and tough. It may be said that the reinforcement shown on the section in the figure was as taken from a measurement of the broken section. It is not known just how the reinforcement was intended to be placed.

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**Marble Production**—The commercial output of marble in 1910 was valued at $6,992,779, and that in 1911 at $7,546,718, according to the U. S. Geological Survey, a gain of $553,939. The production of Vermont in 1911 was valued at $3,394,930, and that of Georgia at $1,088,422.

The value of building marble, rough and dressed, as sold by the producer, was $2,910,267 in 1911, an increase of $552,472 over the value for 1910. Vermont, Tennessee, Alabama, Colorado and Massachusetts produced most of the marble used for interior decorations, the total value for 1911 being $1,545,963, as against $2,001,640 in 1910.

FIG. 3. VIEW LOOKING ACROSS STREAM

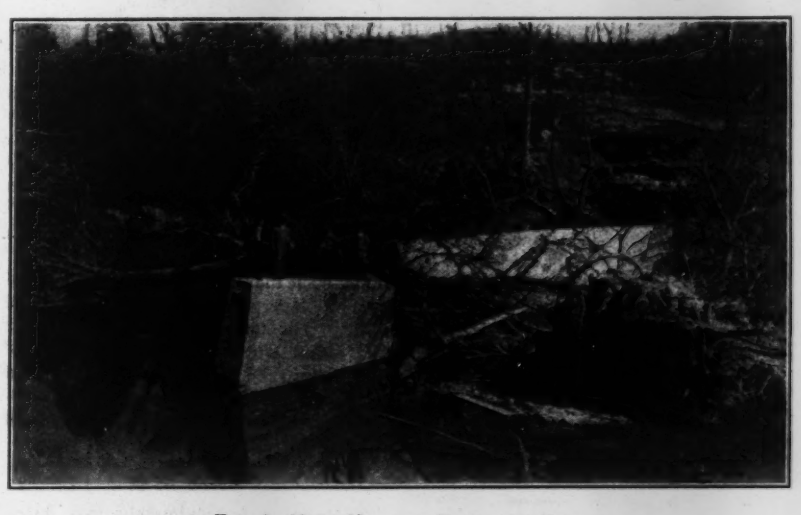

FIG. 4. NEAR VIEW OF DISPLACED END

FIG. 5. CONDITION OF EARTH AT ABUTMENT AFTER DISPLACEMENT

FIGS. 3-5. VIEWS OF SITE OF A WATER-SUPPLY DAM ACROSS THE MUSCATATAUK RIVER, NEAR NORTH VERNON, IND.

(This dam went out very shortly after it was completed)

# Road Construction by the Mississippi River Power Co.

By E. H. Keator*

At Keokuk, Ia., the Mississippi River Power Co. is completing the largest water-power plant in the world, developing 200,000 hp.† The raising of the water level 30 ft. in the river above the dam has made many changes necessary, one of which is the relocating of 20 miles of river road. Owing to the nature of the soil, the topography of the country and the limited area available for the location, some very heavy work was encountered. The two roads, each ten miles long, and distinguished as the Iowa road and the Illinois road, follow the shores of the Mississippi River from Keokuk to Montrose, Ia., and from Hamilton to Nauvoo, Ill., respectively.

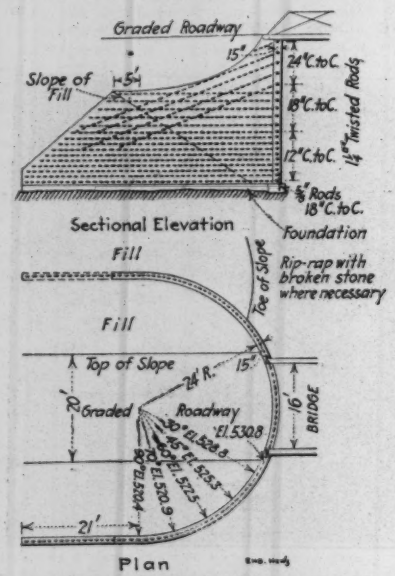


FIG. 1. PLAN AND ELEVATION OF SEMICIRCULAR BRIDGE ABUTMENT AND WING WALLS; MISSISSIPPI POWER CO.

In view of the generally poor condition of the old roads, the power company offered to build roads with 20 ft. of graded roadway and 8 ft. of water-bound macadam placed on one side of the road, with the condition that the counties would bear a small part of the expense. Lee County, Iowa, accepted this offer by agreeing to build all span bridges and abutments necessary, while Hancock County, Illinois, and Nauvoo, Ill., accepted by agreeing to subscribe a fixed sum. With these agreements made, construction work was started in June and the present season's work is nearing completion.

*Engineer of Road Construction, Mississippi River Power Co., Keokuk, Iowa.
†Engineering News, Sept. 28, 1911.

## Iowa Road

By the relocation of 12 miles of the Chicago, Burlington & Quincy R.R. tracks, which throws them back to the base of the bluffs, above the new water level, the new road was forced onto the steep side-hills for a large part of its length. The hills are very steep and this, with the outcropping of white limestone in many places, made the use of ordinary road machinery impossible. For this heavy work we bought a Thew steam shovel, which did the work speedily and economically. Wheel-scrapers were used for the lighter grading and for all fills, except where it was cheaper to load dump wagons with the shovel. All surfacing was done with a road grader and a heavy timber drag, which, with the traction engine, is being kept in operation continuously. This insures a good dirt road at all times with slight expense.

The bridge work done by the county consisted of the erection of seven steel spans, varying from 16 to 60 ft. in length, on reinforced-concrete abutments. To take care of the many smaller waterways draining the bluffs, we built reinforced-concrete box culverts from 24 to 60 in. in size, while vitrified tile was used for smaller openings.

The first half mile of macadam has been laid, and consists of two layers of stone, each thoroughly rolled and covered with a layer of screenings, wet and rolled. The macadam is 8 ft. wide and 8 in. thick, and is placed on one side of the road, while the remaining dirt road is graded to the same height in the center. The other 9½ miles of macadam will not be built until spring of next year.

## Illinois Road

Except for approximately two miles, the grading on this side of the river was much simpler, due to the more gradual slope of the bluffs. The greater part of the grading here was done with a heavy road-grader pulled by a 15-ton combination roller and traction engine. This method proved very efficient on easy side-hill and level work where a long run was possible. A large amount of wheel-scraper work was necessary, and approximately two miles of steam-shovel work through loose and solid rock. This material was handled by the shovel with no difficulty.

The greatest expense of this road was the bridge and culvert work, which averaged approximately $3000 per mile. The placing of 14 steel spans, varying from 20 to 120 ft. in length, on permanent concrete abutments, and the building of numerous box culverts from 24 to 60 in., was required. As there is no railway on this side of the river, the transportation of materials was an important item. Large quantities were carried across the river from the Iowa side in barges. No macadam will be laid on this road until next year, but by July 1 (the date for the completion of the power-development plant) we plan to have open to the public 20 miles of as good macadam road as will be found in the United States.

FIG. 2. SEMICIRCULAR BRIDGE ABUTMENT

## Curved Bridge Abutment and Wing Walls

A special feature of the bridge substructure work on these roads is that wherever a wall of over 8 ft. in height was needed, a reinforced-concrete wall of semicircular design was used. This wall was thoroughly reinforced with 1¼-in. square twisted rods, placed horizontally, and carried the full length of the wall. Enough steel was distributed to carry all stresses in the wall. The side slopes were built to the proper elevation at all points to hold the slope of the fill at 1½ to 1 until the full semicircle was completed. Here the slope of the end of the wall dropped rapidly and was carried under the fill, where all reinforcement rods were anchored. Fig. 1 shows the typical design, and Fig. 2 shows a completed abutment. Where the fill extended over the wall and was subject to water action, stone rip-rap was added as a protection, as shown in Fig. 1.

This wall we found to contain approximately 33% less concrete than any wall of equal strength, and to be adapted to the use of one set of forms for all size walls. We are erecting retaining walls of this type 28 ft. high with a radius of 24 ft. The outside form for this wall is made up of 3-ft. panels, 28 ft. long, placed on end; the inside form is made up of panels 4x5 in., erected in 5-ft.

FIG. 3. MIXING AND DISTRIBUTING CONCRETE FOR SEMICIRCULAR BRIDGE ABUTMENT AND WING WALLS

lifts as required, all panels being bolted. A separate design of wall was made for each case, depending upon the size, foundation, etc., and the radius varying with the height. Fig. 3 shows the construction of the forms and the method of placing concrete in one of the walls, 28 ft. high above the foundation. The concrete is poured from the mixer into a hopper, which is pulled up the inclined frame by a horse-operated tackle, the hopper being dumped automatically at the top of the incline and the concrete distributed to the forms by inclined chutes. The whole scheme we have found easy for erection, and very economical with several walls to be built.

## Soya-Bean Oil as a Substitute for Linseed Oil in Paints*

By Maximilian Toch†

Owing to the high price of linseed oil in 1910, many painting operations were deferred, awaiting a lower price, or inferior materials were used in place of linseed oil. From 1890 to 1909, the price of linseed oil fluctuated between 30 and 50c. per gal. On a few occasions the prices were higher, and in 1896 it went as low as 25c., but a fair average for the 19 years was 40c. Toward the end of 1909, it rose from 60 to 68c. in two months, and by September, 1910, it reached $1.01 per gal. Since then it has been fluctuating between that figure and 55c.

Two substitutes commonly mentioned are fish oil and soya-bean oil. The value of menhaden fish oil has been recognized and it is admitted as replacing linseed oil for many purposes, though it is by no means a true substitute. The principal use is in the manufacture of linoleum, printing inks and paints which are exposed to hot sun or applied to hot surfaces.

In 1909, soya-bean oil, as a paint oil, was practically unknown. Since then many investigators have published accounts of investigations but, owing to the fact that discordant results were continually obtained, it is only within the last year that it has been possible to state with some degree of certainty whether soya-bean oil is a substitute or an adjunct, or neither. The reason for this uncertainty and discrepancy is apparent when it is stated that the author has experimented with 33 different varieties of soya beans and that, in the records of the Department of Agriculture, no less than 280 varieties of soya beans are listed.

The soya bean has been grown in China and Japan from time immemorial, where it has served as a staple article of food. In Europe and America the value and use of the bean have been but little appreciated until very recently, when on account of the scarcity in the cotton-seed supply of the world, soap and glycerin manufacturers began to turn their attention to its possibilities.

All soya beans are leguminous plants which do not tend to deplete the soil of nitrogen. The average height of the plant is about 26 in. The pods resemble those of our sweet pea. They are about 2½ in. in length and are covered with a hairy growth. Generally there are two or three beans in each pod. After the oil is extracted from the bean, the cake is valuable as a cattle food, while the leaves and stalk may be collected for an excellent silage. Practically the entire plant is available for use with the exception of the root.

The average composition of the soya bean varies within narrow limits among different varieties. In the table below are given analyses of a few varieties.

The author obtained discordant results from the soya-bean oil on the market, and his first impression was that the oil might have been adulterated. But the oil in all cases was pure soya-bean oil, though from a seed which was not particularly adapted for making a paint oil.

Through the U. S. Department of Agriculture many varieties of seeds were received, and through the various seed dealers quantities of seeds of all kinds were purchased. The method of extraction followed was to grind the seed very finely in a mill and to digest with gasoline in the cold. The solvent was then evaporated and the oil recovered. The percentage of oil extracted averaged 18%. Though the beans themselves ranged in color from cream white to jet black, it must be noted that all the oils extracted were paler than finely pressed linseed oil and none of them showed chlorophyll extract as markedly as oil from fresh flaxseed. From the various samples of oil it became evident why discordant results were obtained, for some of them dried within a reasonable time and some did not.

It has been stated that soya-bean oil is not as pale as raw linseed and belongs to the semi-drying class. The writer must correct this statement. Soya-bean oils made from cold-pressed seeds, such as "Haberlandt," "Austin," "Habaro," "Ebony," "Meyer" and "Ito San" give excellent results. They have a specific gravity as high as 0.92 with a yield from 16% to 19%. A dryer made from red lead or litharge is unsuitable for soya-bean oil, but a tungate dryer (a mixture of a fused and a precipitated lead and manganese salt of china-wood oil and rosin) acts on soya-bean oil exactly the same as a lead and manganese dryer acts on linseed oil. In other words, a fairly hard, resistant and perfectly dry film is obtained within 24 hr. by the addition of 5% to 7% dryer.

Soya-bean oil (when this name is mentioned hereafter reference is made only to that suitable for paint purposes) is the nearest oil to linseed, and under proper stimulus much waste and unproductive land between Maryland and Georgia, and from the Coast to the Mississippi, will yield productive and profitable crops. The only drawback is the fact that the crop needs much water.

Soya-bean oil appears to consist of from 94 to 95% of glycerol esters. Of these, 15% are saturated acids such as palmatic, and 80% are liquid unsaturated fatty acids containing 70% oleic, 24% linolic, 6% linolenic. The iodine number* of soya-bean oil has been given as from 121 to 124, but the Manchurian cold-pressed oil will average as high as 133.

Soya-bean oil which is suitable for paint purposes has two characteristics which enable the chemist to determine whether a sample is suitable or not. (1) When heated up to 500° F. for a few minutes, it will bleach and remain bleached. Some samples which the author has examined have turned almost water white. Linseed oil has this characteristic but not to the same degree. (2) Cold-pressed oil when heated to 500° F. and blown with dry air from five to seven hours thickens exactly the same as linseed oil and attains a gravity of 0.960 or more. Thickened soya-bean oil has excellent qualities for making what are called in this country "baking japans" and what are known in England as "stoving varnishes." Varnish made from the suitable soya-bean oil bakes very hard and retains an abnormal flexibility.

As regards the wearing qualities of pure soya-bean oil in paint compared with pure linseed oil, the author has had less than three years' experience and can only say that it is not quite as good as linseed. A two-year exposure on a 100-ft. fence gave slightly better results with linseed oil for hardness and with

*From a paper read before the Society of Chemical Industry, New York City, June 7, 1912.

†320 Fifth Ave., New York City.

ANALYSES OF SOYA BEANS (PERCENTAGES)

| Variety | Water | Protein | Fat | Nitrogen-free extract | Fibre | Ash |
|---|---|---|---|---|---|---|
| Austin | 8.67 | 36.50 | 20.55 | 24.41 | 4.00 | 5.78 |
| Ito San | 7.42 | 34.66 | 19.19 | 27.61 | 5.15 | 5.97 |
| Kingston | 7.45 | 36.24 | 18.96 | 26.28 | 4.79 | 6.28 |
| Mammoth | 7.49 | 32.99 | 21.03 | 29.36 | 4.12 | 5.01 |
| Guelph | 7.43 | 33.96 | 22.72 | 25.47 | 4.57 | 5.85 |
| Med. Yellow | 8.00 | 35.54 | 19.78 | 26.30 | 4.53 | 5.85 |
| Samarow | 7.43 | 37.82 | 20.23 | 23.65 | 5.05 | 5.82 |

*The "iodine number" or "iodine value" is the percentage of iodine absorbed by an oil—the test depends on the fact that different oils absorb different amounts.—Ed.

the soya-bean oil for less gloss. A mixture of half soya-bean and half linseed oils showed approximately the same results. A varnish made of 25% china-wood oil with 75% soya-bean oil gave as hard results as linseed oil.

It is too soon to prognosticate the value of soya-bean oil for exterior painting. But for interior use soya-bean oil is the equal in every respect of linseed oil—particularly when treated with a tungate dryer.

Cobalt dryer will, under many circumstances, dry even those soya-bean oils which are not suited for paint purposes, but the present cobalt dryer is rather too expensive. A cobalt tungate is probably the ideal dryer for soya-bean and fish oils. This dryer when present in soya-bean oil to the extent of 5 to 7% will dry the latter within 12 hours.

It is possible to determine and differentiate the mixture of raw soya-bean oil and raw linseed oil, for the iodine values and specific gravities are good indications; but when 25% of soya-bean oil is added to a mixed paint, no one can detect its presence in all instances.

Blown and thickened soya-bean oil is already used by a number of linoleum and oilcloth manufacturers, and for printing ink it presents some advantages. In the manufacture of enamel paint, heavy-bodied soya-bean oil produces most beautiful results, and as perhaps 95% of all enamel paints are used for interior decorative or protective purposes in this country, its use should be encouraged.

It is not within the province of the writer to forecast the future of any paint oil, but there is no doubt that if a campaign of education be urged among the farmers, and proper selected seeds of soya beans are planted, no scarcity in the flaxseed crop will ever again be a menace to the paint and varnish industry. Linseed oil is quoted at 75c. per gal. and soya-bean oil at 55c. When thousands of acres have been planted with proper machinery installed, and sale of cake and ensilage arranged for, then soya-bean oil will sell at 25 to 35c. per gal.

## Annual Convention of the American Civic Association

The American Civic Association, which met in Baltimore, Nov. 19 to 21, had as its main topics city planning, city and national parks and the house-fly campaign. Minor topics considered were smoke and billboard nuisances; the improvement of backyards and the public control of street shade trees.

The presidential address, by J. Horace McFarland, had as its subject "Not Only the City Beautiful." A plea was made for municipal cleanliness, general serviceability and efficiency.

The central feature of the convention was the Wednesday evening session, which had as its presiding officer Walter Fisher, Secretary of the Interior, and as its principal speaker the Honorable James Bryce, Ambassador from Great Britain. Mr. Fisher spoke of the efforts made during the past year to unify the administration of our national parks by the establishment of a federal park bureau. A bill to that end was before the last Congress, but did not progress to the point of a final vote.

Mr. Bryce said, among other things, that the demands for parks and reservations are rapidly increasing with population and with a growing appreciation of their recreational and æsthetic values, but that there is and never can be any increase in the areas naturally fitted for these purposes. He urged the extension of our national park area, particularly in Colorado, the White Mountains and the Southern Appalachians. He also made a plea for a park and forest reserve between Washington and Baltimore, which would serve as a readily accessible outing place for the people of those cities and of Philadelphia. After Mr. Bryce had finished his address, Mr. Fisher stated that the government is making progress in acquiring forest-reserve areas in both the White Mountains and the Southern Appalachians.

The Fly Fighting Committee of the Association, through Edward Hatch, Jr., New York City, urged that "swat the fly" and fly-catching campaigns generally had fulfilled their usefulness as a means of publicity and education and that henceforth the effort should be to stop fly breeding by proper municipal and private cleansing measures.

Under the title "Picture Visits to Three National Parks," there were shown a remarkable series of motion pictures taken during this past season in the Yellowstone, Glacier and Mount Ranier Parks. These views were taken for commercial purposes, but through special arrangement they are being exhibited for educational and publicity purposes in various parts of the country by Lawrence F. Schmeckebier, Chief of the Division of Publications, U. S. Department of the Interior.

Two sessions of the convention were devoted to city planning. At one of these, Walter Burley Griffin, of Chicago, Ill., exhibited and explained his plans for the new capital city of Australia, which won the first prize (£1750, or about $8000) in a world-wide competition. Besides the general plan reproduced in our issue of July 4, 1912, Mr. Griffin showed some enlarged district plans and some colored panoramic views of the site of the new city and of its immediate vicinity. He also showed the general plans submitted by some of his competitors. Mr. Griffin's plans, analytical diagrams and explanatory remarks showed that he had given discriminating study to the problem.

At this same session, Henry B. F. MacFarland, formerly one of the Commissioners of the District of Columbia, outlined the evolution and the revivification of the plan for our own national capital, giving particular credit to George Washington for the original conception. B. A. Haldeman, an engineer of the Bureau of Surveys, Philadelphia, Penn., showed lantern slides of the cities which are to be included in a "European Civic Tour," which is to be made in 1913 under the auspices of the Association.

At the other session given over to city planning, Joseph W. Shirley, Chief Engineer, Topographical Survey Commission, Baltimore, Md., outlined some of the general results of rebuilding the burned district of that city. He said that of the important recommendations made by the advisory commission appointed after the fire of 1904, all but two were carried out: (1) Baltimore St., the principal business street of the city, was not widened from 66 to 100 ft., and another street was not regraded. (2) Of the 140 acres burned, over 10 acres of the former built-up portion were used for street widenings or extensions and 28 acres more were used for municipal docks and markets. The improvements cost $7,250,000, of which $1,125,000 were assessed against private property for benefits. Had the principle of excess condemnation been in force, the city could have effected a great saving in the rebuilding of Baltimore.

J. C. Nichols, of Kansas City, Mo., told how a tract of 1200 acres of land in that city ("Country Club District") is being developed strictly from the viewpoint of making a desirable home-residence section, in accordance with a carefully wrought planning scheme.

The election of officers for 1912-13 resulted in continuing in service J. Horace MacFarland, of Harrisburg, Penn., as President, and Richard D. Watrous, Union Trust Building, Washington, D. C., as Secretary.

**The Vaporization of Metals** from the solid state directly to the gaseous is a subject about which there is little definite knowledge, but which is of considerable importance in connection with the working of metals.

In a paper before the American Foundrymen's Association at Buffalo, in September, abstract of which appears in the November issue of "Metallurgical and Chemical Engineering," Prof. J. W. Richards, of Lehigh University, cited the case of zinc, which boils at 920° C. and which has an appreciable vapor tension at 289° C., or 130° C. below its melting point. This effect is familiar in the cases of ice and to a more marked extent of carbon dioxide snow, but that metals are subject to the same action is less generally understood. The temperature of the metal, the pressure, temperature and chemical activity of the surrounding gas, and the rapidity of flow of this gas over the surface of the metal seem to be factors affecting this phenomenon.

# Annual Meeting of the Society of Naval Architects and Marine Engineers

A large attendance marked the sessions of the 20th annual meeting of the Society of Naval Architects and Marine Engineers, which opened in New York on the morning of Nov. 21, and closed with a banquet at the Waldorf-Astoria on the evening of Nov. 22.

Some important society business was transacted, including the adoption of resolutions on the death of Clement A. Griscom, Past-President of the Society, and on the subject of duties on imports of ship parts and equipment. The following abstracts are from the more important papers in a very interesting program.

### Engineering Progress in the U. S. Navy

In this paper, by Capt. C. W. Dyson, U. S. N., which brought forth extended discussion, the statement was made that under the present conditions to be met in the designing of war vessels, and at the present stage in the development of the two types of marine engines, the Navy Department has been forced to the conclusion that the reciprocating engine has the larger field of usefulness. The paper implied, however, and the discussion strengthened the idea, that for certain purposes turbine engines were superior to the reciprocating type and that for certain other classes of service, a combination of both types in the one boat was most effective.

### Developments in Oil Burning

E. H. Peabody, of the Babcock & Wilcox Co., spoke on this topic, giving a brief historical review of the matter and later outlining the results obtained in extensive tests. It appears that there is some difference of opinion as to whether the first use of mechanical atomizers should be credited to the United States or to England, with a shade of evidence in favor of the latter. However, the paper states that the development of this system for oil burning, which has been found superior to the vaporizing or gasifying of the fuel, is unquestionably to the credit of English engineers, for up to as recent a date as 1907 little attention had been given to the subject in this country. Mr. Peabody's paper traced the steps in the progress of mechanical atomization from its early crude forms up to the present type used, and he gave also valuable information on the conditions and problems incidental to the use of oil as fuel.

### Preservation of Metals Used in Marine Construction

Under this heading a very valuable paper was read by Lieut.-Com. Frank Lyon, U. S. N. Limiting himself to consideration of the metal in the hull and that in the engines, boilers and machinery accessories, he gave, as the causes of wasting away of such metals, corrosion, abrasion, and erosion, of which the latter two effects are comparatively insignificant. Corrosion was explained to be due to electrolytic action caused by the wetting of the contact surfaces of two different metals such as steel and copper, bronze or composition metal, in which case the steel is pitted or disintegrated to an extent dependent on its chemical composition. The body of this paper was devoted to an exposition of the various methods of attacking the problem of preventing corrosion.

### Active Type of Stabilizing Gyro

The use of the gyroscopic principle in a device for eliminating the rolling of ships was explained by Elmer A. Sperry in his paper on the stabilizing gyro. In defining the operating characteristics of his apparatus, he laid particular stress on the fact that in the Frahm "anti-rolling" tanks and other similar devices for eliminating rolling motion in ships, a certain amount of this motion is required in order to actuate the counter forces, so that their action while undoubtedly beneficial is rather along lines of reducing than of preventing the undesirable motion.

The gyroscope, on the other hand, he explained, is a device which was perfected for the purpose of attacking the rolling motion—a resonant effect resulting from the cumulative action of comparatively small but periodic impulses—at its inception and applying small but sufficient counter forces serving to prevent the rolling motion.

### Tool Steel for the U. S. Navy

Under this title, a paper was given by L. H. Kenney on the action of the Navy Department in standardizing the specifications and tests for various qualities of tool steel for use in the Navy, which specifications and tests were, previous to the year 1909, different in each navy yard. The paper was largely devoted to a detailed statement of the kinds of steel required for various tools and the character of the requirements for tests on each quality of steel.

### The Sperry Gyro-compass in Service

Another use to which the principle of the gyroscope has been put was explained by Lieut. R. E. Gillmor, U. S. N. In 1851 the French physicist Foucault determined the underlying principles of the gyroscope in some experiments on the subject of the earth's rotation. These principles are two in number, namely: (1) that the inertia of a rapidly rotating wheel, suspended with freedom to move about all axes, is relative to space, and consequently, that a gyro suspended in that manner will maintain its plane of rotation in space; and (2) that a gyroscope suspended with its axis of rotation horizontal, and with freedom about the horizontal axis partly or wholly suppressed will tend to turn about the vertical axis in an effort to place its plane of rotation coincident with that of the earth. Mr. Sperry has succeeded in adapting these two principles to a device for use in place of the magnetic compass for directing the course of a ship. In brief, his device consists of a master compass which is simply a three-phase induction motor, the rotor turning in a vacuum. The difficulties encountered were in devising means of suspension which would not be affected by quick changes in speed or direction, or by rolling, in providing corrective devices for changes in speed of ship and in latitude, and finally in designing a repeater so that the master compass may be placed in a protected place in the ship and the course directed from the repeater readings at the most desirable place. The cost of a complete installation of this device, including power plant, switchboard, master compass, and five repeaters, together with labor of installing, is $10,000, and it has been already placed on a number of U. S. battleships and on some merchant vessels. It is absolutely independent of the influences which cause errors in the magnetic compass and its maximum error is 0.5° under the worst disturbing conditions.

### Farewell to President Taylor

For the past three years Stephenson Taylor has been president of the Society, and owing to a constitutional provision his reëlection this year was prevented. A fine expression to the esteem in which Mr. Taylor is held as an engineer, as a member of the Society and as a man was paid in an address by Walter McFarland at the closing session of the meeting, seconded by speeches of warm praise from Admirals Watt and Cone and Commodore Miller.

### Election of Officers

The following officers were elected for the ensuing term: President, Col. Robert M. Thompson; Honorary Vice-President, F. R. Fernald; Vice-Presidents, Lewis Nixon, A. P. Niblack and G. W. Dickie; Members of the Council, L. H. Chandler, C. H. McAllister and R. S. Grove, and Secretary, D. H. Cox.

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**Compressor and Blower Tests**—A standard test code for performance tests of compressors, blowers and exhausters, has been formulated by a committee of the Verein deutscher Ingenieure. It is reported by Prof. L. Prandtl and R. Goetze in the "Zeitschrift des Vereines deutscher Ingenieure," Nov. 2, et seq. The code is more a treatise than a test code, and should make a substantial little volume when printed separately.

## Charles Lewis Harrison*

A short note in our issue of Sept. 26 recorded the death, on Sept. 14, of Charles Lewis Harrison, for seven years Principal Assistant Engineer of the East River division of the extension of the Pennsylvania R.R. to New York City and Long Island. The ultimate effect of these several years of work in compressed air was to cause his death while still in the prime of life.

Charles L. Harrison was born at Aux Vasse, Callaway County, Mo., on his father's farm, Mar. 5, 1857. His father, Thomas Harrison, was a veteran of the war with Mexico, and a son of Maj. John Harrison, who emigrated to Missouri in 1818, and Mary Crockett Harrison, a relative of the famous "Davy" Crockett, pioneer and Indian fighter. The Harrison family were from Virginia, where they had been prominent for many years; both Presidents Harrison were descendants of the same family.

His early education was obtained in a country district school. In 1876 he entered the University of Missouri and graduated four years later in civil engineering. At the end of his college course he at once entered into engineering work as a rodman with the Mississippi River Commission, and for several months he was engaged on stream measurements at Fulton, Tenn., and Grafton, Ill. Later he was Assistant on hydrographical and topographical surveys at Lake Providence, La.

In June, 1882, Mr. Harrison was engaged as a transitman on a topographical and hydrographical survey of the Missouri River from Fort Pierre to Fort Randall, S. D., and a year later in the same work along the Red River of the North. He was Assistant Engineer on the construction of a dam across the Mississippi River at Pokegama Falls, Minn., and later Engineer in charge of the completion of the dam across the Mississippi at Lake Winnebigoshish, Minn.

At the beginning of the year 1885, Mr. Harrison left engineering work for a more remunerative occupation, and for five years he was associated with his uncle, B. F. Harrison, in the live-stock commission business in Chicago, Ill. Engineering work, however, had too strong a hold upon his affections to be thus discarded and in 1890 we find him returned to the ranks of the profession as Assistant on hydrographical surveys and investigations for the Sanitary District of Chicago. A year later he was Engineer in charge of the improvement of the Carp River and the building of a sewer system for the city of Ishpeming, Mich.

Mr. Harrison returned to the work on the Chicago Drainage Canal in February, 1892, as Assistant Engineer in charge of surveys and location, and for the succeeding five years was Division Engineer in charge of the construction of Sections 5 to 15, including the regulating works at Lockport. At the end of this work his large experience in river and canal surveys made him one of the best men available for the survey for the proposed ship canals from the Niagara River at Tonawanda to Lake Ontario, and from Troy to Lake Champlain, then under consideration by the U. S. Board of Engineers on Deep Waterways. These surveys lasted from August, 1897, to January, 1900.

The first six months of 1900, Mr. Harrison spent on the Isthmus of Panama making surveys for the Isthmian Canal Commission and verifying the work done by the French canal company. He returned to the States in June and for two years was Chief Engineer of the Denver Union Water Co., Denver, Colo. During this period he designed and superintended the construction of the Lake Cheesman dam (ENGINEERING NEWS, May 12, 1904), notable as sustaining a greater head of water than any dam constructed up to that time.

His work in Colorado so favorably impressed his brother engineers that in 1902 he was called to New York City to take charge of some of the most important and difficult engineering work ever undertaken, the tunneling of East River, New York City, for the Pennsylvania R.R. On this work he was Principal Asistant Engineer from June, 1902, to April, 1909.

In April, 1908, Mr. Harrison suffered an injury of the heart caused by too long a stay in compressed air, from which he never recovered. Although he endeavored to resume regular work in 1909, as Deputy Chief Engineer of the Board of Water Supply of the City of New York, he was compelled to give it up after a year's trial, and from that time he limited himself to consultations. He passed the winter of 1910-11 in California and the winter of 1911-12 in Havana, Cuba, where he became greatly interested in the work of raising the battleship "Maine." In March of the present year he visited the Panama Canal work.

In the latter part of August he contracted a slight cold, which did not take a serious form until two or three days before his death, on Sept. 14. He was buried on the old farm in Missouri.

Mr. Harrison became a member of the American Society of Civil Engineers in 1898. He was a frequent contributor to its discussions, and in 1904 the Rowland prize was awarded to him and to S. H. Woodard for a paper on the Lake Cheesman dam and reservoir. He was also a member of the Western Society of Engineers and of the University and Engineers' Clubs of New York City.

*From data gathered by Alfred Noble, M. Am. Soc. C. E., of Noble & Woodard, Consulting Engineers, 7 E. 42d St., New York City.

## Notes from Engineering Schools

UNIVERSITY OF WISCONSIN—To meet the demand for men trained in forestry, a department of forestry has been organized by the College of Agriculture in coöperation with the State Forestry Board, and will give a thorough course of instruction and practical work in handling timber, timber lands, and farm woodlots. The course covers two years.

This year, work at the university, covering lectures and laboratory work in the principles of forest conservation, the cutting of trees to give maximum perpetual utility of woodlots and forests, logging methods, etc., begins Jan. 7, 1913, and continues to Apr. 15. Students will then make their headquarters in the state forest reserves in Vilas County, making trips to all parts of the forests of northern Wisconsin until July 31. A great deal of this time will be spent in tents and the work will include making roads, trails, firelines, building bridges, telephone lines, and look-out towers, forest surveying, controlling and preventing forest fires, burning slash, studying tree growth and logging methods. Cone collecting, seeding, transplanting and field planting of young forest trees will also be a part of the work.

A number of the best students will be given an opportunity to work about four months in the forest reserves after Aug. 1.

Tuition for residents of Wisconsin will be free. Sustenance in the forest reserves will be furnished by the State Board of Forestry as compensation for the practical work done.

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**The Earthquake Which Occurred** in the northern part of the State of Mexico on Nov. 19, caused large damage to property in the city of Mexico and adjacent towns. Street pavements were displaced, water mains broken and buildings wrecked according to press reports. It is also stated that over 50 people were killed by the collapse of a church at Acambay and that there was a large loss of life in some other towns in the affected district. The earthquake lasted three minutes.

**The Bursting of a Large Feed Pipe,** supplying two hydraulic elevators in the City Court building, New York City, on Nov. 21, endangered the lives of eleven persons in the two elevators. At the time of the accident one of these cars was near the top of the shaft and only a prompt application of the safety clutch saved it from falling. The other car was near the bottom and the occupants escaped with nothing worse than a drenching.

**In a Butting Collision** between two passenger trains on the Seaboard Air Line Ry., near Granite, N. C., on Nov. 19, five persons were killed and five injured, according to the most reliable press reports from Raleigh. Both trains carried a number of passengers and were traveling at high speed at the time of the accident. The northbound train was

about an hour late, and the accident is attributed to the confusing of orders by the engineer of this train. The newspaper accounts state that the killed and injured were all employees and that the passengers in both trains escaped with slight bruises. A fire broken out in the wreckage, following the collision

**Locomotive Engineers' Wages** are to be standardized, according to the decision of the Board of Arbitration, which has for several months been considering the differences between the Eastern railways and the Brotherhood of Locomotive Engineers. The arbitrators fix a minimum wage rate for locomotive runners in passenger service of $4.25 per day's run of 100 miles or less with 50c. per hour for overtime on an average speed of 20 miles per hour. In through freight service the rate is to be $4.75 for 100 miles or less, with overtime pro rata after ten hours. In switching service a minimum wage of $4.10 per day of 10 hours is fixed. The award is to cover the period from May 1, 1912, to May 1, 1913.

The Board declares the interest of the public in the prevention of a general railway strike far transcends the interest of either the railways or their employees and urges the necessity of some means of preventing strikes or lockouts on public utilities. The Board's report is signed by all five of the arbitrators representing the public, but is dissented from in some particulars by the arbitrators for the railways, President Daniel Willard, of the Baltimore & Ohio, and by P. H. Morrissey, representing the employees.

**The Freight Terminal System** of the Chicago & Northwestern Ry., at Chicago, is being extended by the construction of extensive yards at Proviso, 5½ miles west of the city limits, on the main line to Omaha. A new railway has been built, under the name of the Des Plaines Valley R.R., north from Proviso to the Wisconsin Division at Des Plaines, and then northeast to the Milwaukee Division at Blodgett, a distance of 20 miles. South from Proviso the Indiana Harbor Belt R.R. (owned by the C. & N. W. Ry. and the New York Central Lines) extends around the west and southern outskirts of the city, with terminals at Indiana Harbor and Gary, Ind. Thus the two lines form a belt line from a point on Lake Michigan, 20 miles north of Chicago, to another point 30 miles south of the city, and intersecting every railway which enters Chicago. Thus freight between points west and north and west and south can be handled through the outlying yards at Proviso, and kept clear of all city terminals.

The Proviso yard plant represents a cost of about $1,000,000. It covers about 250 acres of a tract of 770 acres, with 56 miles of track and a total capacity of 2750 freight cars. There are four separate yards or groups of tracks, with tracks aggregating 15, 13, 11 and 10 miles. Besides these there are 4 miles of tracks for the engine terminal, which includes a 58-stall roundhouse, a coaling station of the bucket-hoist type, a depressed ash-track, sanding plant, water tanks and water-softening plant, store houses, office building, and a building for the use of enginemen and trainmen. Two viaducts carry highways across the yards. The Des Plaines Valley R.R. is a double-track, built for heavy traffic and equipped with block signals.

**Fire Protection at Temporary Openings**—In the New York subway contracts now in progress, an unusual dispute arose, which has just been settled by compromise. The contracts require the contractor, where he breaks into sidewalk vaults or otherwise into buildings, to erect temporary partitions sufficient to give protection. This clause having reference to protection against weather, it has heretofore been met by putting up weatherproof board partitions, or in a few cases, metal partitions, etc. Some owners erected brick or tile walls inside of these partitions. The fire insurance interests called for increased premiums, under the terms of their policies, on property protected by simple partitions. Property holders protested to the Public Service Commission, for whom the subway work is being done, and demanded that substantial tile partitions be erected. The New York Fire Insurance Exchange stated that a 6-in. tile wall plastered with cement on both sides would be accepted as sufficient fire protection, while the Public Service Commission regarded a plain 4-in. tile wall as adequate. The New York Fire Department agreed with the insurance interests. By compromise a 6-in. tile wall without plaster coat was agreed upon. Such walls will be built at all openings in buildings, and their extra cost will be paid for by the Commission as an extra on the contracts.

**The Westport Wreck** of Oct. 3, on the New York, New Haven & Hartford R.R., is found by C. C. Elwell, Chief Engineer of the Connecticut Public Utilities Commission, to have been caused primarily by the carelessness of the dead engineer and secondly by the short, sharply curved crossover. Evidence was found that the tender was the first part of the train to be derailed, and this derailment occurred after the main line crossover had been passed, and at the point of switch leading to the side track No. 5, on the right (See sketch, Eng. News, Oct. 10, p. 691). The wheels of the forward truck of the tender first struck the ties 44 ft. beyond the supposed point of derailment. The locomotive was finally derailed and turned over some distance farther. Mr. Elwell finds the fact that the engine passed through and beyond the crossover at such high speed to be remarkable, and he feels assured that had the crossover curve not been sharper than 4° the train would have passed in safety. The Connecticut Public Utilities Commission has issued the following orders:

(1) That the New York, New Haven & Hartford R.R. be directed forthwith to remove said facing point switch leading from track No. 3 to track No. 5 (the side track).

(2) When high-speed trains are to be diverted from one track to another and the crossover through which they must pass is not safe for high speed, said trains must be brought to a full stop before switches are set for crossover movements.

**The Reduction of Car Fares** across the Williamsburg Bridge, New York City, ordered by the Public Service Commission for the First District of the State of New York, on April 11, 1912, has been sustained by the Appellate Division of the New York Supreme Court. The order was formulated after a hearing conducted by Commissioner M. R. Maltbie, who found that the company had a fixed capital of $100,735, and a present value of property of $45,400. The annual receipts were $252,387, and the total deductions, including operating expenses, taxes and rentals, were $140,200, leaving a surplus of $112,187. The company claimed further deductions for depreciation and amortization aggregating $6400. Allowing this, the net income was placed at $105,000, equivalent to a profit of 100% annually on the fixed capital, or 200% annually on the present value of property in service.

This operating company was formed by the New York City Ry. Co. and the Brooklyn Rapid Transit Co. in 1904, each taking in one-half of the $100,000 issue of capital stock. The Bridge Commissioner made a contract with this company for the operation of local cars over the Williamsburg Bridge and authorized the company to charge 3c. for a single fare, or 5c. for two fares. The company's contention was based on the claim that a reduction of this rate would violate provisions of the state and federal constitution in regard to contracts. A second contention was that the operation of cars by the allied companies over the bridge was at a loss and that the profits for the bridge operating companies were to be regarded as an offset to such losses. The court rejected both claims.

The total number of revenue passengers carried by the company was between 9,000,000 and 10,000,000 per year, and the average fare per passenger was 2.53c. That the present value of the property is less than one-half the original cost is accounted for by the fact that the company originally built certain tracks, roadway and terminal property which is no longer used.

## Personals

Mr. W. E. Staver', of Montreal, Que., has been elected President and General Manager of the Alaska Northern Ry., succeeding Mr. O. G. Laberee, resigned.

Mr. J. M. Kinkead, formerly Supervisor of the Northern Central Ry., at Baltimore, Md., has been appointed Supervisor of the Pennsylvania R.R., at Huntington, Penn.

Mr. Alfred Noble, M. Am. Soc. C. E., New York City, has been appointed Consulting Engineer to the Public Service Commission, First District, New York State.

Mr. F. M. Barker, Inspector of Transportation of the Lehigh Valley R.R., at South Bethlehem, Penn., has been appointed Assistant Superintendent at Wilkes-Barre, Penn.

Messrs. George Gibbs and E. Rowland Hill, M's. Am. Inst. E. E., have been appointed Consulting Electrical Engineers to the Public Service Commission, First District, New York State.

Mr. S. B. Fisher, M. Am. Soc. C. E., Chief Engineer of the Missouri, Kansas & Texas Ry., St. Louis, Mo., has been appointed Chief Engineer of Construction of the entire Missouri, Kansas & Texas Ry. system.

Mr. Edward E. Slick has resigned as Chief Engineer of the Pittsburgh district of the Carnegie Steel Co., Pittsburgh, Penn., to become General Manager of the Cambria Steel Co., Johnstown, Penn.

Mr. A. M. Acheson, formerly Chief Engineer of the Missouri, Kansas & Texas Ry. of Texas, at Dallas, Tex., has been appointed Chief Engineer of Operation of the entire Missouri, Kansas & Texas Ry. system.

Mr. W. L. Kellogg, formerly Superintendent of Motive Power of the Pere Marquette R.R., at Grand Rapids, Mich., has been appointed Superintendent of Motive Power of the Missouri, Kansas & Texas Ry., at St. Louis, Mo.

Mr. Chester A. Garfield, Assoc. M. Am. Soc. C. E., has resigned as Assistant Engineer, Board of Water Supply, City of New York, to become Assistant Engineer with the Department of Parks, Borough of The Bronx, New York City.

Mr. Robert J. Harding, M. Am. Soc. C. E., for the past five years Superintendent of Public Works of Poughkeepsie, N. Y., has resigned, effective Dec. 1, to open an office as Consulting Engineer at 35 Market St., Poughkeepsie.

Mr. R. P. Dalton, formerly Division Superintendent of the Chesapeake & Ohio Ry., has been appointed Superintendent of the Chicago division of the Pere Marquette R.R., at Grand Rapids, Mich., succeeding Mr. Fred Hartenstein, resigned.

Mr. William B. Dickson, formerly First Vice-President of the United States Steel Corporation, has been elected President of the International Steam Pump Co., succeeding the late Benjamin Guggenheim, who lost his life in the sinking of the "Titanic."

Mr. John Hulst, recently Chief Engineer of the Youngstown district of the Carnegie Steel Co., Youngstown, Ohio, has been appointed Chief Engineer of the Pittsburgh district, at Pittsburgh, Penn., succeeding Mr. E. E. Slick, resigned, as noted elsewhere.

Mr. Wm. F. Robertson, a civil engineer of Charlotte, N. C., has been appointed City Manager of Sumter, N. C., under the new plan of city government. This position was discussed in our editorial columns of Oct. 24, under the caption, "A City Which Wants a General Manager."

Mr. Richard Gould, of Newton, Mass., who, for the past two years, has been associated with Dr. Karl Imhoff in sewage purification work at Essen, Germany, will return to this country in December to enter the office of Robert J. Harding, M. Am. Soc. C. E., at Poughkeepsie, N. Y.

Mr. George N. Randle, M. Am. Soc. C. E., for several years City Engineer of Sacramento, Calif., and recently Superintendent of Streets under the new commission plan of city government, has resigned to take charge of the Sutter Basin reclamation project, a 60,000-acre irrigation project to be undertaken by the Sutter Basin Co.

Mr. Albert S. Cheever, for many years Superintendent of the Fitchburg division of the Boston & Maine R.R., at Boston, Mass., has been appointed Assistant to the General Manager and will be assigned to special work in the operating department. Mr. James D. Tyter, former Assistant Superintendent, has been promoted to succeed Mr. Cheever.

Mr. David White has been appointed Chief Geologist of the United States Geological Survey, succeeding Mr. Waldemar Lindgren, who has been appointed Professor of Geology at the Massachusetts Institute of Technology, as noted in our issue of June 13. Mr. White became associated with the Geological Survey in 1886, just previous to his graduation from Cornell University. Prof. Lindgren will retain his connection with the Geological Survey as one of its geologists, and he will continue to devote some time to his work in the western mining districts.

## Obituary

John Richardson Fanshaw, former Secretary of the Lehigh Valley R.R., died Nov. 19, at his home in Plymouth Meeting, Penn. He was 71 years old.

Phineas P. Wright, former Assistant General Manager of the Lake Shore & Michigan Southern Ry., died at his home in Cleveland, Ohio, Nov. 14, aged 88 years.

Andrew Buchanan, a bridge contractor, of Chambersburg, Penn., died in New York City, on Nov. 20, while attending a meeting of the board of trustees of the Delta Upsilon Fraternity. Mr. Buchanan was born at Vail Mills, N. Y., and graduated from Union College in 1873. He was a charter member of the Engineers Society of Pennsylvania.

## Engineering Societies

COMING MEETINGS

AMERICAN SOCIETY OF REFRIGERATING ENGINEERS.
Dec. 2-3. Annual meeting at New York City. Secy., W. H. Ross, 154 Nassau St., New York.

NATIONAL COMMERCIAL GAS ASSOCIATION.
Dec. 2-5. Annual meeting at Atlanta, Ga. Secy., Louis Stotz, 29 W. 39th St., New York.

AMERICAN ROAD BUILDERS' ASSOCIATION.
Dec. 3-6. Annual convention at Cincinnati, Ohio. Secy., E. L. Powers, 150 Nassau St., New York.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.
Dec. 3-6. Annual meeting at New York City. Secy., C. W. Rice, 29 W. 39th St., New York.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS.
Dec. 4-6. Annual meeting at Detroit, Mich. Secy., J. C. Olsen, Polytechnic Institute, Brooklyn, N. Y.

NATIONAL HOUSING ASSOCIATION.
Dec. 4-6. Annual conference at Philadelphia, Penn. Secy., Lawrence Veiller, 105 E. 22d St., New York.

NATIONAL SOCIETY FOR THE PROMOTION OF INDUSTRIAL EDUCATION.
Dec. 5-7. Annual convention at Philadelphia, Penn. Secy., C. A. Prosser, 105 E. 22d St., New York.

ASSOCIATION OF AMERICAN PORTLAND CEMENT MANUFACTURERS.
Dec. 9-12. Annual meeting at New York City. Secy., Percy H. Wilson, Land Title Bldg., Philadelphia, Penn.

NATIONAL ASSOCIATION OF CEMENT USERS.
Dec. 10-14. Annual convention at Pittsburgh, Penn. Secy., E. E. Krauss, Harrison Bldg., Philadelphia, Penn.

AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS.
Dec. 26-28. Annual meeting at Chicago, Ill. Secy., C. O. Reed, Urbana, Ill.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.
Dec. 30-Jan. 6. Annual meeting at Cleveland, Ohio. Secy., L. O. Howard, Smithsonian Institution, Washington, D. C.

**American Institute of Consulting Engineers**—The question of "Professional Relations" will be discussed at the meeting of the Institute in New York on Dec. 12.

**Engineering Association of the South**—The annual convention of the association is to be held in Nashville, Tenn., on Dec. 6-7.

**Canadian Society of Civil Engineers**—At a meeting of the Electrical Section, in Montreal, on Nov. 21, a paper on "Transmission Line Design" was read by L. C. Smith.

**Municipal Engineers of the City of New York**—A meeting of the Society was held in New York, on Nov. 27, at which time a paper on "A History of the Taxation of Real Estate and the Tax Maps of the City of New York," was read by H. W. Vogel.

**Master Car Builders' and Master Mechanics' Associations**—The regular annual railway mechanical conventions will be held next year in Atlantic City, N. J., as has been the custom for seven years past. For two years it has been rumored that the convention was to be moved to some other location, Saratoga and Washington, D. C., both being mentioned, but it appears that the attraction of the seashore resort with admirable pier facilities for the exhibition, could not be successfully opposed by the rival cities. The 1913 convention will be from June 11-18.

**American Road Builders' Association**—The ninth annual convention of this association will begin at Cincinnati, Ohio, Tuesday, Dec. 3, at 11 a.m. The forenoon will be occupied by the usual addresses of welcome and responses. At 2:30 p.m., three papers will be read on the general subject, "The Organization of a Highway Department," by Major W. W. Crosby, Consulting Engineer, of Baltimore, Md.; W. H. Connell, Chief of the Bureau of Highways, Philadelphia, Penn., and A. N. Johnson, State Highway Engineer of Illinois. Titles of other papers to be presented during the three days of the convention are as follows: "The Development of a Plan for a State Road System," by Col. E. A. Stevens, State Highway Commissioner of New Jersey; "Bituminous Pavements," by George W. Tillson, Consulting Engineer of the Borough of Brooklyn, New York City; "Wood Block Pavements Laid by City Day Labor," by Ellis R. Dutton, Assistant City Engineer of Minneapolis, Minn.; "Cuts in Newly Paved Streets," by H. M. Waite, City Engineer of Cincinnati, Ohio; "The Contractors' Point of View," by Hugh Murphy, Omaha, Neb.; "Plant Equipment," by F. E. Ellis, Manager of the Essex Trap Rock & Construction Co., Peabody, Mass.; "Some Features of Macadam Construction," by T. R. Agg, Road Engineer, Illinois State Highway Commission; "Earth and Gravel Roads," by R. C. Terrell, Commissioner of Public Roads of Kentucky; "Highway Bridges and Culverts," by W. A. McLean, Engineer of Highways, Province of Ontario, Canada; "Economics of Highway Construction," Clifford Richardson, Consulting Engineer, New York City; "Traffic Census as a Preliminary to Road Improvement," by Col. W. D. Schier, Chairman of the Massachusetts Highway Commission; "The Laying of 104 Miles of Smooth Road Surface in One Borough in Five Months," by G. Howland Leavitt, Superintendent of Highways, Borough of Queens, New York City. The Friday morning session will be devoted to the discussion of miscellaneous subjects.